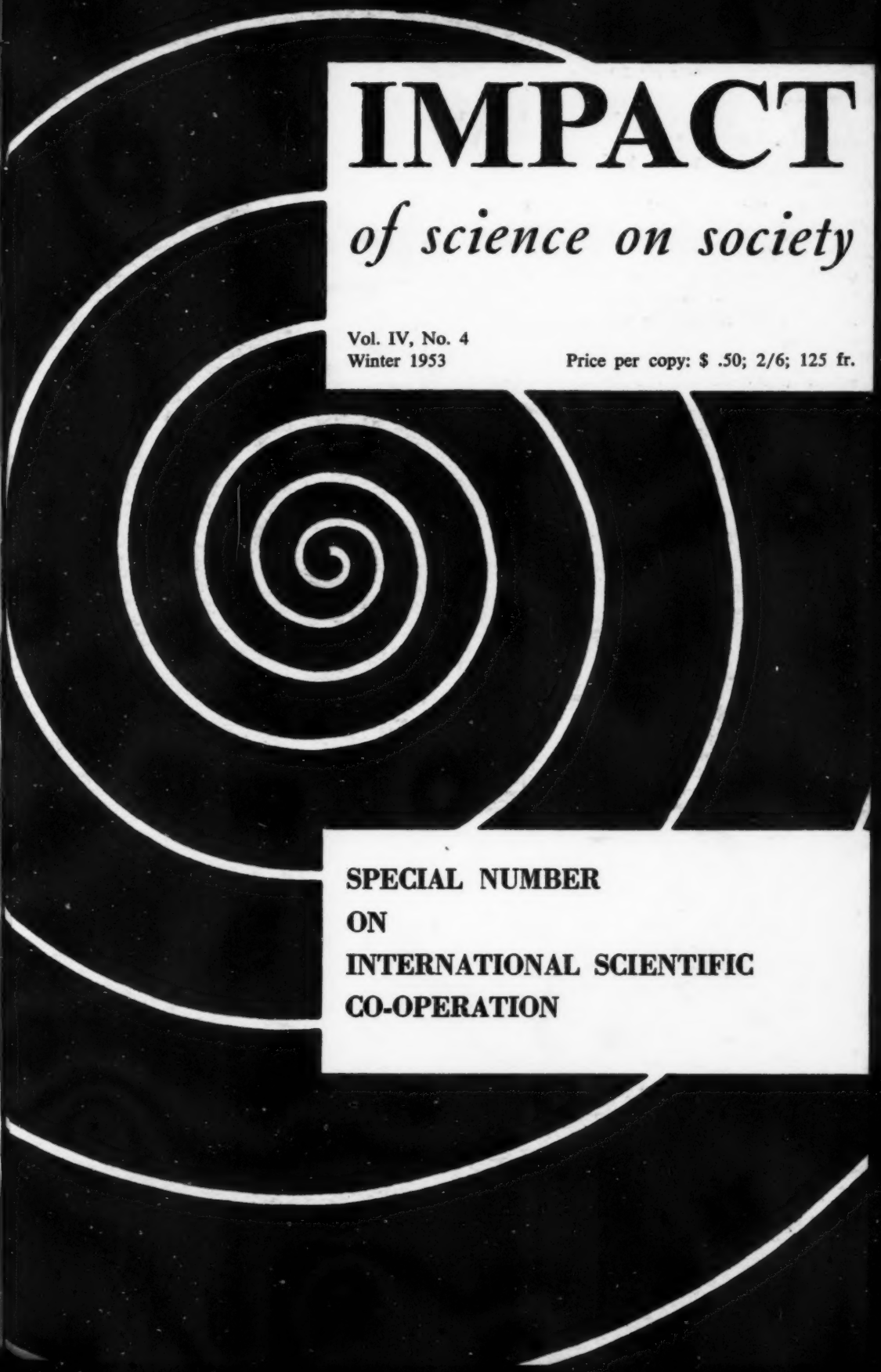
IMPACT

of science on society

Vol. IV, No. 4
Winter 1953

Price per copy: $ .50; 2/6; 125 fr.



SPECIAL NUMBER
ON
INTERNATIONAL SCIENTIFIC
CO-OPERATION

IMPACT *of Science on Society*
quarterly

Annual subscription:
$1.75; 9/6; 450 fr.

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NS 53 I 13A

UNITED NATIONS EDUCATIONAL, SCIENTIFIC
AND CULTURAL ORGANIZATION
19 Avenue Kléber, Paris-16e, France

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ERRATUM AND NOTICE

The Scientific Detection of Crime, Vol. IV, No. 3, p. 164, lines 8 and 11: *for lead* nitride, *read* lead azide.

Science and the Social Order, by Bernard Barber, reviewed in the last issue of *Impact* (Vol. IV, No. 3) has been published in the United Kingdom by Messrs. Allen and Unwin.

INTERNATIONAL SCIENTIFIC CO-OPERATION— ITS POSSIBILITIES AND LIMITATIONS

by

ALEXANDER KING

Dr. King is a physical chemist whom the war drew from research into government, first as Deputy Scientific Adviser to the Ministry of Production, then as scientific attaché and head of the U.K. Scientific Office in Washington. On returning to England he became the first head of the Scientific Secretariat of the Office of the Lord President of the Council. He is now Chief Scientific Officer in charge of the Intelligence Division of the Department of Scientific and Industrial Research, which includes responsibility for overseas scientific relations.

We all pay lip service to the idea of international co-operation in science; it has been with us in one form or another for as long as science itself, and commands approval as an institution, like marriage or the decimal system —at least in theory. In practice, although it attracts great—perhaps even excessive—enthusiasm, it is regarded by the general run of scientists as a mildly useful activity of secondary importance, which seldom impinges on their work. However, since the war the extent of scientific co-operation has greatly increased. International conferences—sometimes of enormous proportions—have been frequent; international agencies, old and new, attempting to establish co-operative activities between their member countries, have achieved a few successes and suffered some interesting failures. All in all, some groping progress has been made towards an identification of those fields of science in which international projects are appropriate and towards an understanding of how and to what extent co-operation is a practical possibility. The number of organizations seeking to secure international co-operation on various aspects or applications of science is enormous. Many of them are regarded as ineffectual but harmless; on the other hand, they encourage a large output of papers, much travelling, interminable discussions which are frequently arid, and the passing of innumerable resolutions which seldom mean very much to the scientists working in university, government or industrial laboratories. There is a feeling that with the ever-increasing demands made by international committees on the time of eminent scientists and with the deterioration in the value of international congresses, this whole activity is getting out of hand and, according to some, falling into disrepute. It is certainly excessively complex and must in the aggregate be very costly. Its useful results are small, and one is inclined to ask whether the game is

worth the candle. The present review is an attempt to assess the position, and to ascertain which are the practical lines of development and whether use can be made in the future of experience already gained.

THE INTERNATIONAL NATURE OF SCIENCE

Science, even more than other forms of learning, can never be nationalized; the constitution of chemical compounds is fortunately the same in all countries; no nationalistic dogma has been able to modify the laws of gravitation; radio-active disintegration is independent of political influence; and the scientific method can be applied to the study of all kinds of systems. We, who have been the unfortunate witnesses of the excesses to which nationalistic concepts can lead, know that the twisting of scientific facts to fit political views always becomes in the end as ridiculous as it is false. The anti-Semitic pamphlet against relativity succeeded in discrediting not relativity but anti-Semitism.

However, science is universal not only in nature but also in structure. Although great research schools within a country have frequently made spectacular contributions to the advancement of a particular branch of science, it is still true to say that in every branch of science the frontiers of knowledge have been thrown back by the efforts of innumerable minds in many countries, with the result that, at any stage in the development of a science, it belongs to the whole world, as a part of the human heritage. This has been obvious since the birth of the scientific method, with the consequence that the results of discovery in fundamental science have always been published freely in journals which, apart from minor pathological interruptions, circulate without obstacle in all countries. The cross-fertilization of ideas thus achieved has enabled the development of science to be rapid; for the solution of a problem by a particular scientist depends on previous partial solutions, on the solution of analogous or even quite different problems, and the elaboration of experimental techniques in universities and research institutes throughout the world. Without access to outside ideas, research schools would soon become sterile and the evolution of science would languish.

An important aspect of international scientific contact has always been the movement of scientists from one country to another, to undertake research, to learn from a master abroad, to lecture, or to attend conferences for the discussion of common problems with colleagues abroad. Throughout the nineteenth century and the earlier part of the twentieth it was customary for those who intended to undertake serious research to spend a year or two in the laboratories of foreign universities after graduation at home. This was a particularly important means of spreading new scientific ideas and

techniques and is again becoming common practice. However, the great increase in the numbers of research workers means that, in the absence of a significant increase in facilities, a much smaller *proportion* than before are enabled to work abroad. The value of international exchange of research workers is recognized not only by academic scientists but also by governments. A particularly significant example is the post-doctorate research scheme of the National Research Council of Canada, which attracts to its laboratories promising and accomplished young research workers from many lands, bringing with them ideas and techniques and receiving others in return.

Until the first world war governments accepted the necessity—or at least the practice—of savants travelling abroad, even in time of war, and facilitated their movement across military borders. The most spectacular cases were Davy's visit to lecture to the French Academy during the Napoleonic wars, and Benjamin Franklin's safe conduct order for the ship of Captain Cook during the difficulties between Great Britain and the United States. Even as late as 1914, the Czar of Russia made possible the return to Germany, after their work had been completed, of scientists caught in the Crimea on the outbreak of war while observing a solar eclipse. The attitude of governments was due less, alas, to a respect for learning than to their ignorance of any connexion between science and practical affairs. Today the reverse has become too painfully true, and governments under stress tend to retain their scientists, now considered permanent assets, within their own frontiers.

The increased interest in science which, for obvious reasons, is displayed by governments all over the world has an important influence on the development of science—both at national and international levels. Its significance for international co-operation will be discussed later, but meanwhile its effect on national activities should be noted. Scientific research is an expensive activity; it requires time, equipment and intellectual freedom to work according to the personal predilection or inspiration of the scientist. Enlightened patronage is thus required if men are to devote their lives to research, the results of which, even when of the greatest gain to learning, can seldom be evaluated by the patron in material terms. Following the accepted traditions of scholarship, patronage in the early phase came from princes and later from merchant princes either directly or, more often, through university endowments. But as rising taxation in most countries made its inroads into private fortunes, the new financiers of science everywhere had to be the governments themselves. Earlier patrons had the rewarding inward glow of the Mæcenas; but governments inevitably want something more in return for the millions they shower upon universities and research institutions. Few of them are so short-sighted as to expect a quick and material return, but they regard their contribution to scientific learning as a necessary national investment and expect their scientists to accept

corresponding responsibilities. Equally in international scientific affairs, only governments can provide the necessary funds. Naturally enough, they expect some evidence of direct advantage to scholarship or economy and are seldom willing to support international co-operation merely because it is a good thing in principle. The scientists who, through enthusiastic idealism, advocate international action as an end in itself have perhaps been the greatest obstacle to the establishment of international co-operation, even where this would manifestly be of enduring value.

In applied science, exchange of technical knowledge between nations has developed in a completely different manner and for quite other reasons. Industrial application is often of great commercial value. Hence, wherever possible, monopoly has been established by the taking out of patents which may be sold to firms across frontiers, and thus exchange of information is put on a payment basis. Firms in different countries frequently have more or less formal arrangements for the exchange of patents and other inventions and, in any case, commercial drive and the demand of manufacturer and consumer for improved materials and goods lead to a quick dissemination throughout the world of new scientific applications. In defence matters, too, technical developments, although guarded with the utmost secrecy, are nowadays rapidly spread from nation to nation by sharing between allies, capture in war, desperate emulation between rivals—or even by less creditable means.

THE INTERNATIONAL SCIENTIFIC UNIONS[1]

Even the least internationally-minded have to admit that a study of the heavens cannot be attempted satisfactorily from a single location. It is not surprising, therefore, that the first proposals for international co-operative work came in astronomy: in 1824 Bessel put forward a plan for a general survey and chart of the heavens to a number of observatories in different parts of the world. The scheme was readily accepted and was followed by a number of other international astronomical proposals; at the outbreak of war in 1914 there were some nineteen independent groups, started on the initiative mainly of individuals or of national academies, carrying out international schemes in astronomy. By that time international agreement was being reached in other sciences; the formation of the Bureau International des Poids et Mesures, founded in Paris in 1875, is an example in point.

1. For a fuller account of this subject, see: F. J. M. Stratton, "International Scientific Co-operation", *Nature, 157,* 96, 1946; and *Development of International Co-operation in Science,* a symposium held in conjunction with the third annual meeting of the Executive Board, *ICSU,* Washington, 18 October 1951, National Academy of Sciences-National Research Council, Washington, D.C., 1952; also *A Description of the International Council of Scientific Unions and of the Adhering International Unions,* ICSU, 1951.

International organizations for particular sciences also began to appear in this period, and by 1900 the International Association of Academies attempted to exercise some degree of co-ordination over these bodies; however, the faulty organization of that Association allowed political considerations to hamper its work. Since membership was by Academies of Science and not by countries, Germany was represented by the Academies of Berlin, Göttingen, Heidelberg, Leipzig and Munich, which tended to vote as a block to overwhelm the interests of other countries. At meetings convened after the end of the first world war in 1918, scientific representatives of the allied powers decided to constitute completely new bodies to which countries which had been neutral would also be invited to adhere. Statutes were soon adopted for an International Research Council to co-ordinate international activity in different branches of science, to initiate the formation of international associations and unions, to direct scientific activity in fields where no international body existed and to enter into relations with governments of adhering countries in order to promote investigations fully within the competence of the Council. At the time of its formation, 12 countries joined the Council; by the time of its transformation into the International Council of Scientific Unions, in 1931, 42 countries were participants.

At the same time as the establishment of the International Research Council, three international unions for particular sciences were formed—astronomy, ever the pioneer in these activities, geodesy and geophysics, and pure and applied chemistry. At subsequent meetings unions were accepted in the following fields: radio-sciences, physics, mathematics, biological sciences, and geography. As the different unions grew in strength and activity, the control of the International Research Council was somewhat resented, and eventually in 1931 it was cast off. The International Council of Scientific Unions (ICSU), which replaced the International Research Council, was given only advisory and co-ordinating functions. This arrangement seems to have operated on the whole successfully, although there is at times some confusion between the rights of the adhering countries and those of the constituting unions, the former having a majority at the General Assembly and the latter on the Executive Committee.

The period 1919-39 saw a great development of activity in many of the scientific unions and the growth of their international prestige. Many of the unions worked through large numbers of study commissions or specialized sections for different branches of their science and each one issued its own publications in the form of monographs, reports, bibliographies and bulletins. Until the war, the Council, with an absurdly small income of about £300, was able not only to cover secretarial expenses, but also to print reports of its triennal meetings and make a small publications grant to its committee on solar and terrestrial relationships.

The second world war brought the work of the unions to a standstill, but

in 1945, after a pause of six years during which science had been applied at an unprecedented rate for purposes of destruction and defence, it became clear that it was to play an ever-increasing part in peacetime human activities. International work, if it were to mean anything at all, would have to be strengthened considerably, and ICSU would have to be in a position to assume leadership. One of the first decisions was to raise national contributions to five times the pre-war rate. Although this was still a very small sum, it gave rise to some difficulties, especially since it increased the national payments from two-thirds to six-sevenths of the total income of ICSU, thus arousing a feeling that control of expenditure was not fairly distributed between countries and unions.

The most important event, however, was the formation of Unesco as one of the Specialized Agencies of the United Nations. Unesco wisely determined at the outset that, in the exercise of scientific functions as in its other activities, it would work through existing and well-established international bodies. Accordingly, in January 1947, an agreement was made between Unesco and the Council, recognizing the scientific unions as providing the natural and appropriate form for the international organization of the sciences, and ICSU as their co-ordinating representative body. Of still greater practical importance was the granting of money to ICSU and the unions to enable them to develop adequate programmes. The Unesco grants-in-aid were particularly important in re-establishing international contacts after the interruption of the war, but they have also been applied to many activities, such as the support of existing and new international publications, travel expenses and subsistence allowances for representatives of the unions attending conferences and symposia, part of the expenses of a few international laboratories such as the High Altitude Research Station on the Jungfraujoch, and the assembly and maintenance of various type-culture collections. ICSU and the unions have, in fact, been receiving since 1947 about $200,000 a year for such purposes. Throughout this period the cost and extent of the Council's activities have been growing steadily while the Unesco grant has dropped somewhat. This colony of international organizations will, in the near future, have to face the alternative of cutting down its activities or increasing its income. The latter can only be done by persuading the countries to pay higher subscriptions, but this will bring back the old fears of control and interference which acceptance of government patronage induces.

Without doubt, the scientific unions form and will continue to form the backbone of international work in the fundamental sciences. They have accepted the challenge of post-war conditions and have been especially effective in the new borderline fields between the older established sciences, but, even apart from the financial problem just mentioned, they face many difficulties. The phenomenal growth of the sciences during the last two

decades has led to complex growth and interrelationships between them, so that it is difficult to see how ICSU and the unions will be able to operate without a complexity and multiplicity of organizations which would make effective action excessively slow. As yet there is not even agreement as to the most desirable form of organization.

A large proportion of the officers of the unions and of their commissions is drawn from amongst the most eminent and creative of scientists, in fact those high-minded and willing people who are always called upon for national or international service. It is important that the valuable scientific time of these people which is thus involved should not mean too great a loss to research. A further and as yet unresolved weakness of the system is that in many countries only a few individuals are involved in the work of a particular union, so that the rank and file of scientists often know little about its significance. If this should become general, the decisions of the unions would be unrepresentative, or even divorced from the real needs of the branch of science concerned. The remedy for this lies, of course, with the national committees rather than with the unions themselves.

THE PROBLEMS OF INTERNATIONAL CONFERENCES

One of the best established methods of spreading knowledge across national frontiers has been the holding of congresses which, in the period between the wars, did much to consolidate the intellectual community of scientists throughout the world. Formerly, these international congresses were attended by no more than a few hundred participants, who could listen to the reading of papers in general meetings, while in the lobbies, on the afternoon excursions and at the banquet, each of the scientists present could be sure of meeting those of his colleagues from other countries with whom he wished to discuss problems of common interest. But even before the war, congresses and conferences were becoming too big and too many. Today they have grown so much in number, especially if international symposia, committees and working parties of the Specialized Agencies and innumerable other international bodies interested in science and its applications are included, that they now represent an extravagant consumption of scientific time and of money. This would not matter much if they were able to fulfil their purpose as well as they did formerly; but some of them no longer do so. Where formerly hundreds attended, now there may be thousands; this ever-increasing number of participants has made many congresses far too cumbersome, while the mounting number of papers read leads to excessive sectionalization. The lobbies swarm with strangers so that it is impossible for the individual scientist, and particularly the younger man, to make contact with those he wishes to meet. This state of affairs cannot be allowed to continue; it must be

cured before it becomes endemic. There is as yet no solution in sight. The international scientific meeting must be preserved as one of the most valuable means of bringing together active research men for that exchange of views on which rapid progress depends, but some way must be found of keeping the meetings small and specialized, so that those really active in a field can meet the few others who are also working in the same field. At the same time, these meetings must not become too exclusive, or limited to those whose reputations are already established. This is indeed one of the most difficult problems of international science.

SCIENTIFIC RELATIONS BETWEEN GOVERNMENTS

Apart from the support of international science by adherence to the international unions and by membership of Unesco and other international organizations, governments are committed to collaboration with friendly neighbours on matters of scientific learning through bilateral cultural conventions which, if acted on with vigour, can be useful. A still further development is the appointment by a number of countries of scientific attachés at embassies and legations abroad. This development arose mainly as a result of wartime collaboration between the allied powers. It was obvious from the outset that the war was to be a technical war which would strain the resources of the opposing powers to the utmost. Complete collaboration, in science as in other activities, for example between the countries of the British Commonwealth, became an important matter of policy early in the war, and the Dominions consequently set up liaison offices in London for the exchange of scientific and technical information with the British service and supply departments. The pioneer nation in these matters was New Zealand which had, indeed, maintained a scientific representative in London for a decade before the war. The practical value of these scientific missions soon became evident, not only as a channel of communication between the Dominions and Great Britain but also between the Dominions themselves. The missions also became the recognized centres in London for most visiting scientists from the Dominions.

In 1942, when the bombs were still falling on London, the officers of the Royal Society, convinced of the significance of this development, set up an informal British Commonwealth Science Committee with their president as chairman and the senior Commonwealth scientists in London as members. This Committee discussed how the fruitful collaboration established under the stress of war might be adapted to the needs of a world at peace. The Committee, in its report published in 1943, invited the governments of the English-speaking countries to consider the possibilities of maintaining permanent scientific representation in London and possibly in other capitals.

Another recommendation of this Committee called for an Empire science conference to be held as soon as conditions permitted. This in fact met in 1946, and, together with the British Commonwealth Scientific Official Conference which followed, established the main principles of post-war scientific collaboration between governments of the British Commonwealth as well as setting up permanent machinery for scientific consultation.[1] There were also close relations between the British Commonwealth and the U.S.A.; in fact, by the middle of the war there was an important American scientific office in London and a British one in Washington; the latter subsequently federated with the scientific missions from Canada, Australia, New Zealand and South Africa to become the British Commonwealth Science Office, which still exists. This unique organization, constructed on the pattern of the Commonwealth itself, consists of groups of autonomous scientific missions from the participating countries housed together and sharing certain common services. The senior man in each mission has diplomatic status and the Commonwealth Science Office is in effect the combined scientific departments of Her Majesty's various embassies and legations in the U.S.A. The advantage of this system deeply impressed all those who had participated in its work, so that the same pattern was later adopted in London, where the scientific missions of Canada, Australia, New Zealand, South Africa, India, Pakistan and Southern Rhodesia have become independent units in a London Commonwealth Scientific Office.

The United States, perhaps more than any other country, has studied the problem of science and foreign relations. The report of Lloyd V. Berkner[2] led to the appointment of a Science Adviser in the Department of State and of a number of scientific attachés in embassies overseas. The United Kingdom, in addition to its Commonwealth and American links, maintains scientific attachés in France, Germany and Scandinavia; some other countries, including Israel, have official scientists in a few of their overseas missions.

These steps towards the creation of official scientific communication lines between governments are of significance not only because of the information which they transmit, but because they tend to become live centres for scientific collaboration. In nearly all instances they have been organized so as to remain relatively free from bureaucratic obstruction. While the creation of centres of government collaboration in science during the war was a step of obvious value, it remains to be seen whether they will survive the period of economy in government spending which we have now entered. The system as a whole is good and provides results which, although they

1. See *The Royal Society Empire Scientific Conference, June-July 1946*, Royal Society, 1948, 2 vols.; and *British Commonwealth Scientific Official Conference, Report of Proceedings*, HMSO, London, 1946.
2. *Science and Foreign Relations (General Foreign Policy Series 30)*, Department of State Publication 3860, Washington, D.C., May 1950. This report was reviewed in *Impact*, Vol. III, No. 1, Spring 1952, pp. 56-59.

cannot be evaluated in terms of money, have an influence far beyond the formal activities carried out.

CHANGES SINCE THE SECOND WORLD WAR

Let us now examine some of the new conditions of the post-war world which are influencing the direction and the magnitude of international scientific work.

Increased Amount of Research and Publication

There is a seller's market for science; it has become fashionable and important; no country can afford to do without it, and it is cultivated particularly for its value in defence, industry, agriculture and medicine. At the same time, governments have fully accepted the notion that science is a tender growth which requires and demands freedom to develop as it pleases and much nourishment in the process. It is very prolific and is encouraged to multiply; for where one research worker stood before the war, laboratory space has now to be built for 10. In all countries, then, the number of science undergraduates is increasing, research schools are booming, the budgets of institutes of applied research are rising steeply—and there is still an unfilled demand for scientists by industry and defence.

What are the international consequences of this state of affairs? Before the war a few specialists in a particular subject in a particular country exchanged reports with colleagues abroad whom they met at occasional conferences. Today hosts of eager young men everywhere are publishing original work and swarming to congresses in the hope of persuading the world of its significance. This alone brings to the problem of international co-operation complications of a new order of magnitude. Publication, still on the traditional international basis, is becoming an ever more serious problem. Some claim that knowledge is now being lost at about the same rate as it is being created—certainly, it is not easy to identify and select that portion of the world's scientific literature which is relevant to one's own work. Scientific abstracting is becoming a serious economic problem necessitating international action. General scientific journals are growing more bulky every month with each of their very specialized papers intelligible to only a handful of people in any country. In the application of science, both the entrepreneur and the government administrator are buried under a mountain of paper.

At the same time, this rapid development of science is bringing into being a large number of borderline subjects, each of which acquires its own techniques, its own technology and its own type of specialists. The fashion

is no longer for chemistry, physics, biology and zoology, but for tribophysics, rheology, geo-morphology, radiobiology and cytology. Each of these new sciences merits its own journal and its own international conferences.

Increased Rate of Development

Science as we now understand it began to emerge at the end of the eighteenth century, almost at the same time as the onset of the industrial revolution. Although these two phenomena were related at birth and their consequences are now thoroughly intermingled, during the greater part of the nineteenth century science did not have very much to do with industry. The great movement of industrialization depended mainly on empirical invention, while science, although it explained certain processes and the working of certain mechanisms, was too occupied in accumulating data and deducing laws to allow of much practical application. By the beginning of the present century, however, chemistry, physics and metallurgy had developed to the point where they could not only improve traditional industries, but also make possible the manufacture of completely new materials, such as synthetic dyes and drugs, and new processes, like high pressure gas reactions or the use of thermionic valves. This gave rise eventually to the great new industries based on science, manufacturing goods hitherto unknown such as automobiles, radios, aircraft and synthetic fabrics, which are gradually changing the whole nature of our material civilization. Firms of this new type live by their scientific research; frequently their boards of directors include scientists who are able to assess the value of new discoveries and ensure that scientific trends are taken into account in making decisions on future design and production. It is natural, therefore, that the industrial significance of a new scientific discovery is quickly recognized today, and great effort is devoted to rushing it through the pilot plant or engineering prototype stage so that production can commence.

Likewise, during the war new discoveries in the laboratory which might be useful for defence or attack were developed with an unprecedented rapidity and applied within a few months or years, whereas previously their development would have required decades or centuries. The outstanding example is, of course, nuclear fission, only just recognized at the beginning of the war, which demanded vast sums spent on new technology and revolutionary production methods before it could be harnessed. Yet in the form of the atomic bomb it proved devastatingly effective before the end of hostilities. This huge acceleration in the rate of development and exploitation of scientific discovery, resulting from the will of nations to survive and to conquer, or from strong economic forces, inevitably exerts its influence on international co-operation.

Increased Cost of Research and Development

Until relatively recently, research in fundamental science was not an expensive activity. The chemist, for example, could investigate new reactions with simple equipment, and even in physics little was needed which could not be made in a university workshop, apart from standard instruments. Since the war all this has changed. Teams of scientists from different disciplines make mass attacks on a problem and, with the present complexity in science, the equipment needed is becoming intolerably costly. Once again the fundamental research workers in nuclear physics are in the lead, and their financial requirements for cyclotrons and synchrotrons run into astronomical figures. This is only one example of a general trend; the science of radio-astronomy, still in its infancy, requires equipment costing hundreds of thousands of pounds, while even the biologist is calling for ultracentrifuges and spectrophotometers, or requiring a stock farm to support his experimental genetics. It is no wonder that governments, having taken over the patronage of science, are beginning to be alarmed by the financial burden and to consider unloading some of their responsibilities on to international authorities, where the costs can be shared.

Governments and Science

The acceptance by governments of the financing of research is already a major influence and has penetrated many different kinds of scientific activity. Universities are increasingly supported by governments; defence preparations are consuming a high proportion of scientific manpower; scientists are being employed in ever greater numbers by governments for research on agriculture, medicine, public utilities, building and construction and, in many countries, to provide much of the background and applied research on which industry depends. The highly-developed countries such as the U.S.A. or the United Kingdom have a high output of scientists from the universities, of which a large proportion are employed by their governments either in national laboratories or, through research and development contracts, in universities and industry. On the other hand, new states such as India and Israel, recognizing in scientific exploitation of their resources the one promising way of achieving a quick rise in living standards, are spending a high proportion of their national income on research. The economic and military significance of science is now so obvious that governments must continue to support it, not as a luxury but as one of the inevitable expensive overheads of contemporary civilization. Although government control of scientific education and research has been surprisingly enlightened in many lands, its very importance entails a change of emphasis, of attitude and of organization. More and more individual scientists are financed by govern-

ments, and hence, directly or indirectly, undertake what governments want them to do. This also applies in the international context. Many of those attending conferences abroad are financed by their governments. In the official international organizations the views expressed by delegates are based on government briefs, although in preparing these advice is often sought from learned societies and other independent scientific groups. There is no turning back to a simpler, freer world. Science permeates all aspects of national life, and governments have therefore legitimate concern with its development. The task facing both scientists and governments in this new situation is to find that balance of freedom and responsibility which can provide conditions favourable to both, and this is as essential in international scientific affairs as it is in the financing of universities.

The International Organizations

The global nature of the war, the breakdown of tradition which accompanied it, and the economic storm which followed it, led to a widespread acceptance of the one-world concept and the creation and support of the UN. This acceptance was not the result of a flash of idealism but of sheer desperation and fear of another war, which science would render still more disastrous and which might extinguish the human spirit altogether. The League of Nations, although it failed in its main political task, had shown how effective international action could be on many practical matters. The creation of UN itself was followed naturally by the building up of the Specialized Agencies designed to provide not only discussion and co-operation but also common action. There is no mention of science in the charter of the UN but most of the Specialized Agencies and in particular FAO, WHO and Unesco are concerned with scientific co-operation in their own fields. Granted that the insertion of the "s" in Unesco was an afterthought, it has nevertheless, especially in the early formative period, been a solid pillar of stability and enterprise in that organization.

All these bodies are, of course, supplied and controlled by their member states, and delegates at general and other conferences represent the interests of governments. Nevertheless, through national co-operating committees, the scientific briefs for delegates are mainly based on the advice of independent scientists. As already mentioned in connexion with ICSU, it is essential that the giving of such advice should not become the monopoly of a small group in any particular country, since this could mean that the Unesco science programme would have little meaning to the mass of scientists of that country.

Apart from the Specialized Agencies and commissions of UN, there is a vast number of special organizations covering practically every branch of pure and applied sciences. Many of these are intergovernmental organiza-

tions, operating on contributions from governments and holding meetings attended by government-appointed scientific delegates. Others, such as ICSU, are semi-governmental, still others are non-governmental organizations whose members are learned societies or corporate bodies in the various countries.[1]

The activity, significance and value of these organizations vary greatly. While they all function by bringing together people of many nations for discussion of particular problems of common interest, only a small proportion attempt to undertake or stimulate joint work.

Technical Assistance

After the war there was a strong and natural urge in many countries to assist refugees, relieve need and help to build up again on the ruins. Unesco, in common with other international bodies, undertook relief and rehabilitation in its own field of education, science and culture. It was, however, insufficiently financed to do this on a broad basis and worked mainly by mobilizing, on a world-wide scale, national or private resources for reconstruction. One of the most successful schemes supplied scientific and technical equipment to war-devastated institutions and schools.

A further scheme for technical assistance developed later as a part of the Marshall Plan devised by the U.S.A. for assisting in the economic reconstruction of European countries. This made possible, among other things, visits of specialists, managers and work-people from European countries to the modern and efficient industrial plants of the United States. It also supported many other means of transferring "know-how" from the United States to Europe and, through the European Organization for Economic Co-operation (OEEC), it was extended to stimulate co-operation between the countries of Western Europe. Technical assistance to the underdeveloped countries of the world expanded rapidly as a result of President Truman's Point Four speech; it operates through the various nations and the Specialized Agencies, contributions being provided by the United States and other countries. The work of the different specialized organizations in this field is co-ordinated by the Technical Assistance Board in New York. A further technical assistance scheme is the Colombo Plan of the British Commonwealth countries, which aims at speeding up the economic development of the countries of South-East Asia.

As a result of these schemes many experts have visited the underdeveloped countries, giving advice on agriculture, medicine, education and various other matters. Laboratories have been equipped and training schemes put

1. Some 200 of the more important of these organizations are included in the *Directory of International Scientific Organizations*, published by Unesco in 1950.

into operation. Technical assistance is in the main an enlightened political weapon which, in trying to build up standards of living and economic stability, makes large use of the applied sciences, and is furthering a rapid transfer of knowledge and technique from the highly-developed to the under-developed countries.

The Shrinking World

The rapid development of communications, resulting from the application of new scientific knowledge, is in its turn having an important influence on international scientific co-operation. Indeed, were it not for the availability of high-speed transport, the technical assistance schemes would necessarily run at a much reduced pace, and the number of international scientific conferences would be greatly diminished. It is quite possible, for example, for a busy European scientist to attend a lengthy conference in Australia and yet be away from his own country less than three weeks. This annihilation of distance, so characteristic of our times, makes possible collaboration between the nations to an extent impossible hitherto—though at a high cost in money and a still higher one in human fatigue.

All these features of a transformed world are having a dominant influence on international scientific work; they have changed the needs, the possibilities, the means and the achievements, which now offer a striking contrast with the easy if limited collaboration which existed up to 1939. Adjustment to the new circumstances is by no means complete, and many countries and organizations are striving to work out the best methods of common action. A few cases will now be given to illustrate the methods adopted.

THE CONCEPT OF INTERNATIONAL LABORATORIES

At the time of the formation of the UN, full-scale international activity seemed highly desirable, and even necessary. The success of the few international research institutes, such as the zoological laboratory at Naples and the Jungfraujoch High Altitude Station, suggested to many people that the creation of a considerable number of international research centres under the UN would be of great value to science and at the same time to world peace. The French delegation therefore submitted to the Economic and Social Council, in October 1946 (i.e. about the time Unesco was being created), a resolution inviting the Specialized Agencies to submit a report on the problem of establishing UN research laboratories. Astronomy and tuberculosis were cited as two possibly suitable subjects. It is interesting to note the following three reasons given by the French in support of their resolution:

A large number of research activities in various fields would be much more effective if conducted with all the requisite resources of perfectly equipped international laboratories for which UN would be financially and intellectually responsible;

secondly,

where man is fighting the unknown, intellectual comradeship acquires extraordinary strength and value—if every scientific victory is made a joint triumph, scientific research will have acquired its true meaning;

thirdly,

an imperative need of democracy in the international field is that small countries with limited budgets should not suffer in their moral and intellectual development from purely material inferiority.

The resolution was accepted by a large majority and the Secretary-General carried out an extensive enquiry on the question amongst the Specialized Agencies, international and national scientific bodies, and individual scientists. The response was undoubtedly favourable to the establishment of international laboratories, but many bodies, taking the principle for granted, and without critical thought, seized the opportunity to put forward plans for new institutions in their own field—and a large number of brightly-painted hobby-horses were trotted out. A brief summary of the types of activity suggested for international laboratories should be of interest. Some, fired with internationalist idealism, indicated a desire for laboratories in fields of vital concern to all nations, especially in agriculture and medicine, for the purpose of relieving distress and improving living standards. These replies seldom considered whether such institutes would in fact be more effective than existing ones on a national basis. Another group suggested in the general interest that international laboratories be set up for the study of subjects neglected for some reason or another. Again there was no thought as to why UN support should succeed in fields where free intellectual choice had failed to attract research.

Most useful, perhaps, were those replies which concentrated on research fields that can only be rationally developed on an international level, such as the ever-recurring projects in astronomy, but also subjects in geophysics and the social sciences, as well as problems of areas such as Antarctica or the oceans of the world, which are beyond the confines of any one state. Finally, the establishment of international laboratories was recommended by some for working out and maintaining units, symbols, nomenclature and standards which are of international significance.

Negative arguments were also put forward, based mainly on the high demands which such institutions would make on the limited finances of UN, and the danger to existing laboratories by the drawing away of their best scientists to untried international institutions. Also, of course, the inveterate individualists held up their hands in horror at the very idea of international

institutions, while those sensible if uninspired people who always urge caution and slow growth suggested that a start might be made by co-ordinating existing activities.

The Secretary-General's report was presented to the Economic and Social Council on 10 August 1948, and, at the same time, the French delegation submitted a new resolution commending the principle of international laboratories and asking for further discussion of the problem by national scientific organizations and by a small committee of experts. In spite of much critical comment, this was accepted.[1]

A committee of experts was duly convened. Each served in a personal capacity and the chairman was Dr. J. Needham. They enthusiastically endorsed the need for vigorous international action in science, including the establishment of UN laboratories. The committee discussed the various subjects against the criteria of (a) general and scientific importance; (b) appropriateness for international treatment; (c) existence of facilities on which to build; (d) cost and lack of duplication with existing research centres. From a very large number of possible topics, the following was the priority suggested: I: (a) UN International Computation Centre; (b) UN International Institute for Research on the Brain; (c) UN International Institute of Social Sciences. II: (a) UN International Laboratory for Arid Zone Research; (b) UN International Astronomical Laboratory; (c) UN International Institute for the Chemistry of Living Matter; (d) UN International Meteorological Laboratory.

In addition, and with special reference to the technical assistance programme, the committee suggested that consideration be given to the possibility of establishing a fluid and solid mechanics laboratory, an erosion laboratory, a mining laboratory, an institute for the humid tropical zone, a geo-medical centre, an institute of oceanography and fisheries, and one for the study of social diseases.[2] The report of the independent experts was debated by the responsible non-experts at Ecosoc in August 1950, with strongly expressed views both for and against the proposals. In the end a resolution was voted which merely requested Unesco to make an appraisal of the priority order, evaluate the competence of existing centres and analyse the need for specific regional or UN laboratories, including staffing and financial plans. It did, however, recommend that special consideration be given to the computation centre.

Thus, after a great deal of talk lasting more than four years, these high and ambitious plans were passed over in tentative and uncertain form to the Specialized Agency to deal with more or less as it saw fit. It would be

1. *The Question of Establishing United Nations Research Laboratories*, Lake Success, UN Department of Social Affairs, December 1948.
2. *Report of the Committee of Scientific Experts on International Research Laboratories*, Doc. E/1694, Lake Success, Economic and Social Council, May 1950.

interesting to know how many of the Ecosoc delegates were advised by their scientists, and if the rather negative agreement reached reflected, therefore, not only the political and financial uncertainties of the scheme, but also a lack of conviction that it was intellectually sound.

INTERNATIONAL RESEARCH WITHIN UNESCO

Unesco itself caught the international-laboratory fever early—and met its first failure in the field with the Hylean Amazon scheme. Since that time it has moved carefully and tentatively in several directions, has accumulated much experience and achieved substantial success. Following the Hylean Amazon debacle, an attack was made on the subject of arid zone research, one of the second priority items of the committee of experts. In many ways this was an ideal subject for international enterprise. Desert and semi-desert conditions persist in many geographical and all the political zones of the earth. Yet the problems are not completely intractable, and any progress towards solution might be of widespread economic value. The problems themselves are full of scientific interest and challenge and, by their very nature, occur mostly in underdeveloped areas where existing research is piecemeal and tentative. Thus all the economic, idealistic and environmental conditions exist for an international approach with the support of both scientists and their governments. The first attack was on the obvious conventional lines—an "International Institute for Arid Zone Research". This, however, met with immediate opposition on financial, political and organizational grounds. But out of it grew the concept of an Advisory Committee on Arid Zone Research, charged with the task of co-ordinating existing information and formulating the precise problems, stimulating existing national institutes to greater effort and, with Unesco support, aiding publication, exchange of workers and the holding of international conferences of active research workers in the various subjects constituting arid zone research. This method of approach was agreed upon, and the Committee is now a very useful body which commands international respect. In its formation, Unesco scored a major success and, far more important, it showed that it could learn from experience and was sufficiently flexible to recommend the right organization to fit the job.

Unesco also accepted the Ecosoc invitation to consider the formation of an International Computation Centre and held the usual meetings of experts prior to lauching the project at its General Conference. This was perhaps not quite such an ideal scheme as it had seemed in the remoteness of Ecosoc. There was some confusion as to whether it should be a research or a service centre, or both; furthermore, although the equipment for such an undertaking is expensive, many countries were already investing in it on their own

account. The trend of interest in the project indicated that, should a computation laboratory be set up, it would have to be in practice a European regional rather than a world laboratory; the small size of the political units which form Europe and the ease of communication between them would increase the day-to-day value of a common computation research and service institute. After the 1951 General Conference, a sufficient number of countries agreed to the proposals but, alas, an insufficient number have ratified the agreement, so that the scheme still languishes. Is this a case where scientists have not been able to obtain the necessary government support for their international plans, or have they themselves had second thoughts?

An example of a still different type has been the setting up of the European Council for Nuclear Research. The idea came from a suggestion of Professor Rabi, of Columbia University, at the General Conference of Unesco at Beyrouth, and after preliminary expert consideration it became clear that the subject was ripe for international action on a regional basis. European scientists, feeling themselves somewhat cut off from advances in high-energy physics, owing to the war, security barriers, shortage of dollars and the astronomical cost of experimental equipment, were ready to work together. Furthermore, the subject is one which appears significant to governments. The sharing of facilities, brains and expenses appeals to them as a good economic proposition. There have been considerable problems both of organization and of a political nature connected with this scheme and, as always, difficulties in agreeing upon a site for the institute. However, these have been solved; countries have promised their support, plans for the high-energy generators are well advanced, and Geneva has been chosen as the site. This project gives promise of being one of the strongest and most useful precedents of international scientific enterprise to date, and such success as it may achieve will be due to an identity of interest on the part of both scientists and governments. It will be particularly significant as precedent.

THE PERILS OF COMPROMISE

Many more examples of scientific collaboration or of the approach to it have come from UN and the Specialized Agencies. The Atomic Energy Commission was an interesting if frustrating development; the UN Scientific Conference for the Conservation and Utilization of Resources, held at Lake Success in 1949, had useful repercussions, especially on the technical assistance programme. Many of the special commissions have had a definitely scientific slant. The other novel approaches to collaborative research have, however, been outside UN and, indeed, come mainly from the regional organizations.

Before going on to discuss the regional approach, something should be said about the practical limitations of international research in post-war conditions. These limitations become obvious more from listening to debates on scientific subjects in general than from studying the fate of individual projects. Delegates at general conferences and even specialist working parties are a rather mixed bag; some are eminent scientists and specialists, others are directors of government or private research institutes, others again are scientific administrators sent by governments, and there may also be a sprinkling of embassy diplomats sent to hold a watching brief but with little if any instruction from home. Such a mixture of backgrounds is inevitable, and is not generally disadvantageous so long as the individuals are well briefed on the subject and on opinions about it in scientific and government circles in their home countries. Far more serious is the diversity of views, that is of responsible scientific views, on practically any aspect of the application of science. A moment's thought will show that nothing else could be expected because of the extreme range of environments and circumstances represented. The delegates come from large countries and small countries, rich ones and poor, tropical, temperate and arctic, industrial and agricultural, new republics and ancient hereditary monarchies, island communities and continental powers; in fact, they represent such a variety of interests and needs that it is difficult to synthesize a view on any topic which is both sensible and acceptable. It would be a mistake, however, in stressing this diversity of view, to give an impression of discord or unwillingness. On the contrary, in these meetings, where a common scientific training and a willingness to understand the other fellow's point of view prevails, there is a mutual respect and tolerance which is rare in international meetings of a more political character. It is simply that extremely different needs and possibilities are difficult to reconcile in any constructive way. The harmonious nature of these debates is, of course, conducive to compromise, and this is where the weakness of the whole system emerges; for the reconciliation of opposites frequently produces little more than a resolution of woolly platitudes, an invitation to somebody else to do something vaguely useful or rather pointless. Alternatively, a good-natured or a tired committee, prodded by a few enthusiastic specialists, may agree to accept some idealistic but unworkable scheme. But as in the end governments have to pay, few of these schemes survive, although before their demise, some of them generate much hot debate and difficulty at both the national and international level.

If the inherent difficulty facing full-scale international work is that most schemes acceptable to everyone are of use to none, the solution is surely to be found in the design of smaller plans between groups of nations with sufficiently close interests and sufficiently similar needs for the inevitable compromise to be of common use. There is already a trend in this direction, including a number of Unesco schemes, where it has become clear that

interest in a project initially open to all crystallizes in a particular region. This spontaneous movement towards regionalism, together with the recent creation of schemes of a deliberately zonal pattern, based often on political relationships, makes it necessary to examine the possibilities of the regional approach in order to ascertain whether the ultimate solution of international scientific co-operation is to be found there.

TYPES OF REGIONAL ORGANIZATION

Regional research schemes may be devised for groups of nations assembled on a basis of some common political tie, geographical proximity, a common environment, or possibly a combination of these. Some examples of each of them will be mentioned before discussing one of them in detail.

Political Regionalism

One of the most natural and useful moves of this type is that between the countries of the British Commonwealth, based on an intimate knowledge of one another's needs and progress. The Commonwealth Science Conference of 1946 was organized to enable senior research workers from these countries, and directors of research councils and institutions devoted to non-defence purposes, to re-establish relationships interrupted by the war. A standing committee was established consisting of the heads of the national research councils or scientific and industrial research organizations of each country, together with a working party of their representatives which meets frequently in London. Thanks to this machinery and to the proximity of the scientific liaison officers of all the countries in the British Commonwealth Scientific Offices in London and Washington, there is an easy day-to-day relationship which ensures that each is aware of the other's interests and problems. Small specialist conferences are organized from time to time, exchange of research workers between the countries facilitated and a large number of common activities stimulated. This type of easy informal co-operation is thoroughly effective, but it has grown gradually over many years and in a "family" environment. It could probably be created only in similar circumstances.

One particular bilateral case of co-operation within this group which has an especial interest was the U.K.-Canadian atomic energy project during and after the war. This scheme, which was located in Canada so as to be remote from possible enemy air attacks, was a thoroughly successful partnership on a large scale. Workers in large numbers and from many sciences were recruited in both countries. Although the scientific director was usually drawn from the United Kingdom, the management of the project was fairly

and squarely on the shoulders of the host country. The scheme was indeed brilliantly managed and lack of dual authority reduced the possibility of friction to a minimum. Some of those who have given much thought to these matters and who speak from experience insist that a single administrative authority, preferably vested in a national organization from which the international enterprise has grown, is essential for success. For example, Dr. W. Albert Noyes, Jr., speaking as chairman of the Chemistry Division of the United States National Research Council, concludes: "At the present time it would seem probable that a laboratory (international), to succeed, would have to be under the auspices of one organization or of one government which would control the finances but which would receive help by appropriations from other governments or from private agencies."[1]

A further example of political regionalism (which is at the same time geographical) is the scientific and technical work of OEEC. It will be discussed separately.

Geographical Regionalism

In the worldwide reconstruction which followed the war, it was often found convenient to organize co-operation between neighbouring countries with economic, social and other problems in common. Scientific co-operation, of course, was often included. The work of the Caribbean Commission is an interesting example, for here is an area vast in extent, consisting mainly of isolated groups of islands, many of which are dependencies of Great Britain, France, the Netherlands and the United States. Social, nutritional, health and agricultural problems are similar in these different political units, which all have great problems of communication. The Commission includes a research council which, although it has not started many co-operative schemes, has done much by bringing together experts from the different territories for the study of common problems, and has made possible the exchange of information on many topics of vital importance to the area.[2]

A different type of regional organization and one devoted exclusively to scientific topics is the Scientific Council for Africa South of the Sahara. It had been realized for many years, as was pointed out in the Rhodes Memorial Lecture by the late General Smuts in 1929, that "different and often conflicting principles were being applied in the different parts of Africa, in the scientific and other fields, and that little was known of what was taking place in the continent as a whole". Following this plea, an African research survey, financed by the Carnegie Corporation, was undertaken; from it

1. See *Development of International Co-operation in Science, supra*, p. 8.
2. *Annual Reports of the Caribbean Commission to the Governments of the French Republic, the Kingdom of the Netherlands, the United Kingdom and the United States of America*, The Crown Agents for the Colonies, 4 Millbank, London, S.W.1.

emerged, in 1938, Lord Hailey's *African Survey*. The desirability of some deliberate action was evidently recognized, but it was not until 1949 that an African regional scientific conference was held in Johannesburg at the instigation of the South African Government; and it was from its resolutions that the existing Council was derived. This Council was established by the governments of Belgium, France, Portugal, Southern Rhodesia, the Union of South Africa and the United Kingdom, and its members are eminent scientists chosen as representatives of the participating governments in order to secure a good coverage of the sciences of direct interest to their area. A very active secretariat has already assisted greatly in establishing working contacts with existing national and international specialist groups in Africa, in organizing meetings of experts to discuss common problems and in encouraging the work of existing organizations.[1]

The Pacific Science Council is another and earlier regional body, which works mainly through its congresses. There is also an organization with research interests for the South Pacific rather similar to the Caribbean Commission. In 1951 a Pan-Indian Ocean Science Association was formed by Australian and Indian initiative, open to all nations on the shores of the Indian Ocean. A further regional body of a different and more local character is the Nordic research council formed by Norway, Sweden, Denmark and Finland.

In this regional category comes the European Council for Nuclear Research already mentioned—a particularly important experiment since it is the first major scheme with no aims other than the advancement of science, undertaken on an international basis for reasons of economy. It remains to be seen whether it can be efficiently and harmoniously run by an international administration, but the outlook is bright; whether it is a success or a failure. it will yield much experience for future guidance.

Environmental Regionalism

By this is meant collaboration on problems inherent in a particular type of environment which is not concentrated in a single geographical area. The best present example is the Advisory Committee on Arid Zone Research formed by Unesco, whose members come from the many parts of the world where desert conditions prevail. A preliminary survey of the desirability for "humid tropic" studies to be organized in an analogous way is being made; oceanographic research, which is creeping into programmes of some of the regional bodies, comes into the same category. There are as yet few organizations devoted to such work, but one can imagine a number of topics

1. *First Report of the Scientific Council for Africa South of the Sahara*, August 1952, P.O. Box 21, Kikuyu, Kenya.

for which this type of regional co-operation might be the most effective form; e.g. there could be common research and development on the utilization of terrestrial steam between countries geographically and politically as diverse as Italy, Iceland, New Zealand and possibly Japan.

INDUSTRIAL RESEARCH

International arrangements in industrial research have operated smoothly for many years through the sale of patents and by transactions between industrial firms in different countries. In addition, there are international organizations for discussion of general problems; amongst these may be mentioned the World Power Conference, the International Institutes of Refrigeration and of Welding, and the International Committee for Scientific Management. Very little international co-operative industrial research had, however, been done before the war, mainly because of commercial difficulties. Since then, however, the drive for economic co-operation between nations and the emergence of problems relating to the use of raw materials and natural resources have stimulated international work in this field also.

So far, the most comprehensive approach has been made for the limited area of Western Europe through the Organization for European Economic Co-operation (OEEC). This is primarily an economic organization and one of the most successful of the international bodies formed since the war, possibly because of the relatively small number of countries participating in it and the similarity of the problems confronting them. In July 1949, the Council of OEEC agreed to a proposal put forward by the British delegation that there should be a working party on scientific and technical information to advise the Council on any further measures of collaboration in scientific matters which might influence economic development in Europe. The working party, as then established, later became the Committee of the Organization for Productivity and Applied Research, while a few months ago an executive agency, called the European Productivity Agency, was created with independent funds to continue its work and secure the implementation of its recommendations.

The first step was to advise the Council on the establisment of a programme of technical assistance visits to the United States whereby scientists and engineers from the various member countries travelled together to investigate American developments in particular industries. A complementary system of inter-European visits has been created on the assumption that there are many aspects of industrial research and application where the more highly-developed countries of Western Europe can make available information which might contribute to the general European economy without detriment to themselves.

There is an effective sub-committee for co-operative research. The scientists attending it come mainly from the various national research organizations, and are therefore concerned with applied research. They agreed at the outset not to discuss the organization of fundamental scientific research, since they are convinced that this must remain free of all unnecessary restrictions if it is to be fruitful; applied research does not allow of the full intellectual manœuvre and free choice of lines of development which characterize the fundamental sciences. Furthermore, the development stage between discovery in the laboratory and production in the plant costs very much more than the research stage, and it is in this intermediate phase that OEEC has stimulated so much useful collaboration.

Much of the detailed work is done by meetings of experts instructed to study specific problems, participants at these meetings coming from research associations, universities, trade associations and government agencies, as well as from nationalized and private industry. The general aim behind this work is to raise the level of productivity in the European states. It is considered that in the long run the rate of assimilation of new scientific ideas is one of the dominant factors in determining productivity. In large countries, such as the United States or U.S.S.R., there is a whole sub-continent without tariff barriers as a market. In the United States, for example, when national interest or the demands of manufacturing industry necessitate the development of an expensive technical process, it can be undertaken in a single place, whether by individual or government initiative, and the results exploited throughout the whole vast area. In Europe such conditions are lacking, since each small political unit possessing sovereign autonomy has until now had to undertake all the technical development necessary to support its economy or else to pay royalties on patents for the use of inventions from abroad.

Until the war this presented no great difficulties, although it was an expensive system which encouraged low innovation rates and, hence, a too slow increase in productivity. Now, however, it is manifestly impossible for each small European country to develop independently the chemical pilot plant and engineering prototypes which are necessary if it is to maintain the high standard of living which only an advanced industrial economy with healthy exports can provide. The demands of defence worsen the situation greatly, since modern warfare uses equipment of an ever-increasing complexity which depends for its development on the work of an excessively large proportion of the best technical brains of each country as well as on great capital resources and a large slice of national income. One alleviation would be an extensive use of co-operative research.

The scientists at OEEC, accepting the economic arguments for regional co-operation in scientific development, considered a list of topics suggested by the different countries. From this they chose two, as experiments from

which to learn something about the way practical collaboration might be accomplished. These were the generation of electricity by windpower and the low-shaft blast furnace fed by oxygen. Both of these are problems of utilization of natural resources and were selected because they were not only costly but relatively free from commercial complications. In the windpower project the experts decided that no large-scale collaborative work was at the moment necessary, but they effected much useful exchange of precise information on measurement and design, and established contacts which will long persist.

On the low-shaft blast furnace, plans were put forward for a common experimental production unit, since it appeared unlikely that useful results could be obtained through small-scale tests. Initially some nine nations combined to finance and operate this general scheme, which was created not as an OEEC organ but as an independent body—in fact as a small development company free from the difficulties and delays inherent in a large international organization. The low-shaft blast furnace has been constructed in Belgium, adjacent to a plant which can supply sufficient oxygen for its operation; it is of novel design and is aimed at the utilization of low-grade ores and fines, and particularly of coal or lignite which cannot be used as substitutes for metallurgical coke in the conventional blast furnace.

It was discovered early in the OEEC deliberations that particular countries were interested in very different types of co-operative project, according to their resources and needs. Hence it was agreed that, in each case, only those countries which considered it in their national interest should be expected to join in the financing and operation of any particular scheme.

After these initial experiments, a number of other projects were given detailed consideration by the experts. Some of these have led or are leading to co-operative work, others have resulted mainly in arrangements for exchange of detailed information. Out of this work has been created a European Organization for Research in Photogrammetry; regional research projects are being planned on the economic removal of salt from water by a number of different processes—a matter of great importance in many areas—and on new methods of producing metallurgical coke from coal of a non-coking type. Studies have also been made on methods of producing phosphate fertilizers with less sulphuric acid than at present, on the properties of blends of man-made fibres with wool, the utilization of low-grade ores, underground gasification of coal, and many other technological subjects. Schemes have also been worked out for the exchange of information between the member countries, including the answering of specific industrial technical questions.

Parallel with this technological work, other investigations of a more economic type are being undertaken by the scientific section of OEEC, including measurement of industrial productivity, research on human factors

in industry, work study techniques, simplification and reduction of variety in industry, the influence of fiscal policy on productivity, and many other subjects where exchange of experience and the working-out of common methods may yield results which can be applied generally. The European Productivity Agency, which is now continuing this work, will be able to speed it up by the employment of consultants providing background information so as to enable the groups of experts to reach conclusions more quickly; on the non-technological side of its activities, it will finance research, perhaps mainly of a sociological and economic type. The success of this work to date is due to the flexibility of the system which does not put even a moral obligation on a member of the organization to join any particular co-operative scheme. The only criteria for co-operation are economic advantage and technological promise, and only those nations with a real interest in the problem and a need to solve it are brought together in any particular project. These conditions are conducive to agreement on objectives and on scale of operation; they form indeed the basis for a really constructive partnership.[1]

THE PRESENT AND THE FUTURE

This picture of international scientific activity is one of bizarre complexity. The total effort is enormous and is very costly both in the time of the scientists and the money of the taxpayers. It is perforce an exceedingly inefficient system, even though it does produce some results of permanent value. This is a painful conclusion for one who has worked for international co-operation in the sciences, but it has to be faced because much of the effort has been made in the hope of building for the future, and the new edifice can never be strong and stable if its foundations are weak or misshapen.

In spite of the present unimpressive record of achievement, the need for international co-operation in science, as in other activities, is uncontroversial on scientific, economic and political grounds. Its continuation and growth are inevitable, but the present vague recognition of this will have to be replaced by precisely formulated concepts in those fields of endeavour where the international approach offers real advantages over the already existing national projects. The technique of developing international activities must also be remodelled so as to take advantage of experience gained and to take account of the new trends and conditions outlined earlier. Much more requires to be done; and it must be done better, more efficiently and, above

1. In this connexion, see: A. King, "European Co-operation in Applied Science", *The Times Science Review*, London, Summer 1952.

all, with the willing co-operation of a much larger proportion of scientists in the participating countries.

For the normal international transactions of the fundamental sciences, the complex of ICSU and the scientific unions, which is an organic growth, should have the flexibility to adapt itself to the new circumstances. In these matters they are the most suitable bodies to assume those general functions which are genuinely and completely international, such as agreement on nomenclature, standards and symbols for the sciences, exchange of information, and discussion of common problems such as the provision of abstracts of the literature. These bodies have special importance for such sciences as astronomy, meteorology and oceanography, in which the field of observation cannot be confined by political boundaries, and in the planning of international programmes of work. It is unikely, however, that the scientific unions could develop with profit a chain of laboratories, not only because of financial restrictions, but because of the difficulties inherent in the organization of completely international institutes of a vital character. ICSU itself might however from time to time pass to Unesco well-considered suggestions for common work on particular subjects in regard to which strong need was felt and which for special reasons called for international action. A thorough study by ICSU of the problems of organizing international congresses would be timely, with a follow-up to ensure that those relating to the work of its unions were models of effective assemblies for the fruitful exchange of ideas. The success of ICSU and of the unions depends in the long run on the influence they have on the work of research scientists throughout the world. This influence, though difficult to exercise, is all the more important to achieve in subjects where research is mainly of a laboratory type which is already being done effectively on a national level so that obvious need for international action is small. It would be interesting to know, for example, what proportion of chemists and physicists are aware in any detail of the work of ICSU and the unions, and to what extent their work would suffer if there were no unions for these subjects. Both needs and results must be made obvious in international work. The problem of finance for the unions is closely related to this difficulty, for the only hope of obtaining increased support from governments is by demonstrating the real value to science of the unions' work.

When the sciences are applied to problems such as agriculture, erosion, forestry, building and industry, quite different conditions prevail and a quite different organization for international co-operation is required. Economic aspects cannot be excluded, and any attempt to exclude them merely evades an increasingly important issue. Science has great economic and commercial value; it is by the effective use of science that nations survive and rise from poverty to prosperity. Governments, as custodians of the peoples' well-being, today have to take responsibility for applied science and to encourage or

withdraw from international co-operation according to their interests. To succeed, therefore, international projects in the applied sciences must offer great promise of concrete value and provide some clear advantage over national effort. As has been said, it is unlikely that this will often be true of co-operation planned on a completely international scale, where compromise between a large variety of interests will often mean that nothing of practical value is achieved. Co-operation between smaller groups of nations for a particular purpose gives greater promise of success, and this grouping of nations need not be on political grounds but merely on grounds of common problems. Preferably, too, the attack should be on a well-formulated single problem rather than on a more general field of applied science. This has the added advantage that the scope of work need not be so great as to necessitate an entirely new international laboratory, but rather an extension of the use of the existing national institutions best fitted for the particular task—with consequent simplification of administrative problems. It would be particularly useful if regional councils, even where they are not set up primarily for scientific co-operation, could, by conducting surveys and convening meetings of experts, help in the identification and formulation of specific problems requiring research and development which might with advantage be undertaken collectively for the benefit of the whole area.

The most obvious reason for participating in international scientific projects is the considerable saving to each member through the sharing of costs or of scarce expert manpower. It should therefore be more frequent in technical development work than at the less costly research stage. Nevertheless, there may in future be an increasing number of cases, as has happened in nuclear physics, where equipment is so costly that it is only by sharing the burden between a group of neighbours that facilities can be provided at all. Still another situation where common research might be sensible would arise when something new of importance had to be developed or applied rapidly whilst centres of research were absent or very meagre. This might happen, for example, in the study of the application of the social sciences to industrial problems in Europe, or in a whole variety of fundamental research fields in a less highly developed area.

In industrial research, it has been found advantageous in many countries to set up institutes for co-operative research in particular industries, such as the research associations of the United Kingdom or the TNO institutes in the Netherlands. The research done by these organizations is paid for by groups of firms, many of whom, in addition, run their own very substantial research laboratories. It has been found, however, that certain types of problems, particularly those of background interest to an industry as a whole, are specially appropriate for co-operative effort, while others, especially those of immediate commercial value, are best handled by the individual firms themselves and not shared with rivals. This same principle

applies to international co-operative research in industrial science, which is likely to be concentrated, at any rate in the first phase, on development and utilization of natural resources, matters of public utility, basic industrial processes, or topics of interest to nationalized industries, rather than on more competitive developments where nations are rivals.

The success of regional enterprise of this type will depend not only on the appropriateness of each project but also on its efficient management. If possible there should be, amongst the workers, nationals of all the participating countries. In that way greater scientific and technical value results, for unless a member has his representative on the job, learning the techniques, acquiring "know-how", gaining experience of the difficulties and failures encountered, the teething troubles and the precise conditions for success, he might just as well be content with a paper report at the end. There are vested interests in science as in most other activities; the director of a national research institution will naturally and wisely consider a remote connexion with a piece of international research as a poor substitute for doing the job himself—even if it is a success, event if its results are presented in intelligible reports, even if it costs him and his country a mere fraction of what it would cost if carried out by him alone, and even if his financial contribution entitled him to a share in the patents. Directors of research, unless enthusiastic internationalists, are not therefore easily persuaded into advocating international co-operative work. Participation of their own scientists in the project is the best way to break down this very understandable resistance and the most effective way of stimulating international partnership.

So far, most of the practical experiments in regional co-operative research have taken place in Europe—this is natural because of the co-existence of a number of nations of approximately the same political structure and state of development. Similar regional developments should become possible in Latin America. It would be more difficult to achieve results of this kind in areas such as the Middle East, where political differences render co-operation between neighbour states with common problems unlikely for the present. Still more difficult is the situation in regions where all the states are at an early stage of development, lacking both research facilities and trained men, and perhaps even administrative experience in such things. Yet it is such a situation, dominated by lack of resources, which calls most clearly for a sharing of the burden. In these circumstances, it might be possible, through the vehicles of technical assistance, to persuade one or more of the developed countries to help in the organization of regional work in the less developed areas. Possession of scientific skill, experience and laboratory resources has become a matter of national prestige, and technical assistance, in spreading this knowledge and skill with the aim of economic improvement, has become an enlightened economic and political technique which could be usefully employed in initiating and encouraging regional co-operative activities. In

any case, the Specialized Agencies might well devote some study to the question of regionalism.

In a few cases, concrete co-operative schemes arise spontaneously out of need, and through the enthusiasm of a few people. This has been the case in an interesting scheme between France, the United Kingdom, the Netherlands and Sweden for the investigation of flame radiation with respect to furnace design and operation. In most instances, however, some central agency will be required to provide a forum before selection of suitable projects can be made by the expert, and also to act as a repository of experience in the organization of co-operative schemes. The Specialized Agencies and particularly Unesco are already doing this, but it might well be made a more deliberate part of a policy of regionalism. Experience at OEEC, where careful expert attention has been given to these matters, has shown that only in a few of the cases considered does a concrete suggestion for common research come forward, although in nearly every instance some degree of collaboration ensues. There is a whole spectrum of possibilities, from which the following stand out:

1. The creation of an international or regional laboratory.
2. Internationalization of an existing national institute by contribution of men, money and problems, but retaining it under its original management.
3. Distribution of individual new projects, all relating to a single problem, to existing laboratories in different countries, with or without shared payment and manpower.
4. Consultation of experts on a broad subject, say building research, followed by acceptance, by individual laboratories in the region, of responsibility for concentrating on a particular topic or topics within the subject and making the results known to the other institutes of the region. Workers from abroad might be accepted at the centres where the research is concentrated, and each nation, while agreeing to the concentration of a topic in a particular institute, would not relinquish its right to work on that topic in its own laboratories, and should indeed be encouraged to do so if it has the resources.
5. Consultation of experts in a given field, who conclude that no precise projects for co-operative work are obvious; but the consultation results in detailed exchange of information, visits to one another's laboratories and possibly exchange of workers.

CONCLUSION

International collaboration in scientific research and development can be extremely valuable and should be strongly encouraged by international

bodies, governments, research institutions, and individual scientists, but only under certain conditions. The chief of these is that the projects be appropriate for international effort and show promise of real advantages over normal national or institutional means. These advantages may for example be a saving to each participant of men, resources or finance, or a speeding up of the work. In other words, co-operation should be based on real needs rather than on idealistic or political principles.

Mention has already been made of the harmony which prevails at so many international scientific meetings. This is due to a community of interest and experience, which frequently transcends nationality and makes it possible to reach agreement. It has been the object of this paper to be critical in pointing out certain obvious present weaknesses in international scientific work; but the successes already achieved, minor though they be, are nevertheless greater than in most other international activities. If, by skill in choosing really appropriate research topics and in operating them in the common interest, this functional approach to the overall and supreme problems of international amity can be made effective, it will be a major contribution to international political technique and to general human well-being. Thus, international scientific co-operation *can* be of scientific, economic and political value. The game is well worth the candle, but it must be played with consummate skill.

THE ARID ZONES— AN INTERNATIONAL TASK

by

JAMES SWARBRICK

James Swarbrick, after working for several years with the British Council, joined Unesco in 1951 and is now in charge of the arid zone programme.

The Sahara is an "ideal" desert, and probably most people tend to think of a Saharan landscape, or what fiction and the cinema have portrayed for them as a Saharan landscape, when the word desert is mentioned. This idea of a desert—an endless expanse of sand, a burning sun, two or three palm trees in the middle distance and an Arab riding a camel, wrapped in a burnous and romance—is so firmly fixed in our minds that it may be surprising and even shocking to learn that scientists find it hard to agree on a definition of a desert. Yet even the popular connotation of the word desert has changed over the centuries. The biblical desert was not so inhospitable to the Israelites as modern imagination makes it, and in the Latin word *desertum* the emphasis was on abandonment, emptiness and the absence of fellow-humans, rather than on the elements most prominent in the present-day notion of a desert.

One difficulty about defining a desert is that it has no sharply-defined physical limits, except seawards. The deserts shade off so gradually with slightly improving conditions that nowhere can one say—like the man in the Spanish verse who was able to declare triumphantly, as he bestrode the Manzanares, that he had one foot in Pinto and the other in Valdemoro—that here desert conditions end and the temperate zone begins.

The major difficulty, however, in arriving at an agreed definition of a desert and its sub-divisions—it is usual to speak of extremely arid, arid and semi-arid areas—is that so many factors are involved, factors, moreover, which influence each other, such as rainfall, temperature, insolation, evaporation, relative humidity, vegetation and soil composition. Each specialist tends to define a desert in terms of his own subject. As a general approximation, however, we may take it that an area in which the rainfall is very small (averaging below 100 mm. per year) and seasonally uncertain, and in which the average annual temperature is high, will be arid, while an area with greater rainfall, up to an average of about 500 mm. per year, will be semi-arid.

Areas of aridity occur in all the continents, and over the whole world amount to something between one-quarter and one-third of the land surface.

There are, however, five great dry provinces: the North African-Eurasian, the North American, the South African, the Australian and the South American. A glance at the map[1] is sufficient evidence of the enormous area of the world which suffers from aridity.

Can anything be done to improve the world's deserts and near-deserts? Is there any hope of reclaiming them so that they may contribute towards alleviating the under-nourishment from which so many millions suffer today, and from which many more millions will suffer in the future unless agricultural production keeps pace with increasing birth-rates and improvements in prophylactic medicine? A great deal can be done and is in fact being done, all over the world—in research laboratories, in experimental stations, in government departments, in the deserts themselves. Let us look briefly at the major problems in desert reclamation, and try to see what promise there is for an improvement in man's living conditions, both in the arid areas and outside them.

There is one great problem common to all arid areas: lack of water. This lack may be absolute, because no rain or very little rain falls, or it may be relative, because what rain does fall is not available to support a utilizable vegetation on account of factors such as insolation or the nature of the soil. So in some arid areas the problem is to find water supplies, and in others the population must be protected against drought, and planned use must be made of what water there is.

When rain falls on the ground, some of it remains in the upper levels of the soil and either is used by plants or is evaporated. Some of the rain, however, sinks into the earth, where it may be drained away by streams and rivers, or it may remain underground, travelling very slowly through permeable rocks. If these rocks can be reached from the surface by boring, then the water can be lifted by pumps and used for drinking purposes and for irrigating plants; or, if the water-bearing rock is between two impermeable strata, the water will gush out as an artesian well.

Some of these underground reservoirs are fed from vast catchment areas, so that even the small proportion of the scanty rainfall which reaches the underground in a semi-arid country represents a very considerable quantity of water when measured in cubic metres. Geologists are searching for underground water in all the world's deserts, using the methods which geophysical research has provided for them. In the area around Mexico City alone, over one hundred wells are being bored every day. Scientific research and equipment are constantly improving our knowledge of where water is to be found and of the means to reach it.

1. This map is based on special maps prepared for Unesco by Peveril Meigs and showing the distribution of arid homoclimates. They have been published in *Reviews of Research on Arid Zone Hydrology*, Paris, Unesco, 1953.

Rainfall in arid areas, though deficient, often results in floods which cause erosion, since the water loosens and carries away with it the upper soil layer. Thus not only is the water wasted but the land is impoverished. The damming of rivers and the building of reservoirs to impound flood water are thus imperative. The ancient civilizations of the Middle East and the Mediterranean basin were skilled in these methods of conserving water supplies. At the present time India leads the world in irrigation from rivers, but the planned development of river resources is going ahead wherever rivers flow through arid areas.

Evaporation from the surface of impounded water can represent a serious loss in arid areas. The construction of deeper reservoirs with corresponding reduction of area is one way of reducing the loss. A more radical solution is to allow the water to seep underground through specially prepared percolation beds and store it there, to be pumped up as required. The city of Los Angeles, for instance, recharges its underground aquifers with treated sewage waters. But such a solution is not universally applicable in arid areas, where reservoirs generally have to serve the double purpose of regulating river flow and providing hydro-electric energy.

Water supplies, either from underground or from rivers, as supplements to deficient rainfall, are limited. Though, unlike coal, they are not exhaustible, they must be managed with care. Research is needed to determine the safe amount that can be abstracted. If this safe amount is exceeded, the water table will become progressively lower, costs of pumping will rise, wells will have to be deepened and the rate of flow will drop. Moreover, even when these water supplies are completely utilized, great arid areas will still be undeveloped. Two processes, neither of which has been fully investigated, give hope for some at least of these waterless regions.

If an economic method could be devised whereby the salts could be removed from sea water and from the salty underground water which is all too frequently found, perhaps the greatest single step would have been taken towards desert reclamation. Look at the map of the world's deserts, and see how many of them lie along the coasts, especially the western coasts of the continental land masses. The coastal deserts of Chile and Peru are extreme examples, where, with the sea in sight, water has to be brought by pipe line or even by railway tank cars from the other side of the Andes.

So far no process has been discovered which will permit the removal of the salts from sea water at a price that would allow the large-scale utilization of the water. Of course, if you are mining for oil in a desert your profits may be such that you can afford to distil salt water, but you would not attempt to irrigate a field or a garden that way and hope to make a living out of the proceeds.

The problems are very great, but they are not considered to be insurmountable. In the United States, the President has set up the Office of Saline

Water Research, with a budget of $2,000,000 spread over a five-year period. The feeling in the U.S.A. is that not only can the problem be solved if sufficient resources are put into the attempt, but that—for the future prosperity of the south-western part of the country—it must be solved. And an economic method of purifying salt water would benefit not only the arid parts of the world but coastal cities in the temperate zones. Cities are, in effect, man-made deserts, where the rainfall goes largely to dilute the sewage, and they must seek their water supplies for human consumption and industrial uses often from great distances.

Another possibility of increasing water supplies which research has opened up is that of artificially provoking rainfall. Acute controversy has raged on this subject, but now passions are cooling and sufficient data seem to have been collected for outlining a picture of what can and cannot be done in rainmaking. No one can make rain fall out of a cloudless sky, or indeed unless cloud conditions are favourable. Often, however, rain-bearing clouds cover the sky and the air becomes humid long before rain falls, or the clouds may disperse without precipitation occuring at all. In these conditions it may be possible to cause rain to fall by any of several processes. The most usual techniques are either to "seed" the clouds with solidified carbon dioxide (dry ice) or with silver iodide, or to vapourize silver iodide in a generator on the ground, so that it rises into the clouds. There is no danger of rainmaking exhausting the supply of rain, or causing areas now humid to suffer from drought, for the natural rainfall accounts for only about 1 per cent of the available moisture in the atmosphere.

Rainmaking is still in the experimental stage, and is still expensive. But research is being vigorously pursued, especially in the United States, Australia and Africa, and there are good hopes that in a few years' time certain marginal areas now useful only as temporary pastureland may be able to bear crops, and that the area of seasonal pastures may be extended.

A problem secondary only to that of water supplies in arid areas is the provision of energy. Energy is needed for pumping water, for domestic and farm use, for industry, for the exploitation of mineral wealth; energy is needed above all to remove the pressure that exists in all arid areas to cut down trees and shrubs for fuel. One cannot sell the idea of afforestation and conservation to people whose immediate need is firewood.

Increasing attention is being paid to the development of means of harnessing the sun and the wind to meet the energy requirements of arid areas—especially rural communities—which are remote from fossil fuels or hydro-electric power. Of course usable wind speeds are not available all the time nor, even in the desert, does the sun shine throughout the 24 hours of the day, so that these energy sources need to be supplemented or converted into another form of energy which can be stored. Wind energy, for

instance, can be converted into electrical energy by a windmill running a dynamo. The electrical energy can then be used in an industrial installation so arranged that a large number of processes can be carried on intermittently, while continuous processes, cut to the minimum, are operated from another fuel source when wind energy is insufficient. Alternatively the electrical energy can be stored in batteries, but this is a very expensive method. A process of storing electrical energy that would be cheap to install and maintain would enormously extend the usefulness of windmills as energy sources in arid areas. For the moment their scope is largely limited to the provision of energy for domestic and farm use.

There are many who believe that the greatest hope for an economic energy source lies in the sun. Research is going on in many parts of the world on ways of using the enormous surplus of energy which reaches the earth from the sun. In India a solar cooking stove has been perfected, in France tremendous temperatures have been achieved by concentrating the rays of the sun with concave mirrors, in other countries attempts are being made to utilize the temperature difference between the upper part of the sea, warmed by the sun, and the colder, lower part.

Though man experiences difficulty in harnessing the sun's energy for his needs, plants do not. For plant growth in arid areas the limiting factor is not the length of day or the amount of light as it so often is in temperate climates, but water. Factors such as light, rainfall, temperature, wind, soil condition and constitution, and methods of cultivation make up the environment of the plant, and the study of plants in relation to their environment is the object of plant ecology. It is obviously of primary importance for the development of agriculture in the arid zones to discover those plants that do best there and the reasons why they thrive, as well as to try, by selective breeding, to produce varieties of plants that will withstand drought and high temperature. The selection and breeding of plants capable of tolerating salty soils or salty irrigation water is also very important. The most valuable contribution made by increasing the nutritive value of the forage plants in desert pastures is not so much that it enables more beasts to be fed from a given area, but that it reduces the pressure of cropping on the plant cover, thus arresting erosion and soil deterioration.

The prevention of the spread of deserts is at least as important as the reclamation of areas which have been deserts for thousands of years. Land on the fringes of deserts is in a very delicate equilibrium, and unless great care is exercised in using it, and especially in cultivating it, this equilibrium will be upset and the desert will inexorably march on. There is no need to remind anyone of the losses represented by the "dust-bowl" areas in the United States in the thirties. The methods of preventing the establishment of new dust bowls are now well known, and the application of contour ploughing,

the setting up of wind breaks, the prevention of floods, and above all scientific knowledge of what a given area can and cannot produce, are able to prevent new areas of erosion. Unfortunately these methods are not always applied, and there are all too many places in the world where, for lack of knowledge or the will or means to apply it, land is going out of cultivation and pasture is becoming steppe.

A widespread misconception is that tractors and artificial fertilizers are the cause of erosion and of the destruction of the soil. Obviously a man with a tractor can plough up more land that should never be ploughed than a man with a mule, and artificial fertilizers, if easier to apply than farmyard manure, need much more skill and knowledge in their application. But it is precisely in the areas where land is cultivated by one man and a mule with little or no fertilizer that dust bowls are being created today. And the remedy, unfortunately, is not easy to find. A piece of land that should be left fallow or sown for pasture is ploughed and cash crops grown on it all too often because the farmer needs the return from the crops. The return grows smaller each year, but to the poverty-stricken a diminishing return is still a return.

In the foregoing pages I have tried to sketch some of the main problems of the arid areas, problems which vary from country to country but are still strikingly similar in all the world's desert and semi-desert tracts. The problems are great, but in considering each one of them we have dwelt on the past, present and future contribution of scientific research to their solution. For the improvement of living conditions in the deserts is inseparably linked with man's progress in scientific and technical knowledge. The deserts are to the temperate areas as the poor labourer to the rich man. The living conditions of the poor, at least in the industrial areas of the West, have changed more fundamentally as a result of the advance of basic scientific research and technological progress than have those of the rich. A room in a cottage lit by one electric light bulb is much further removed from the same room lit by the tallow dip of a hundred years ago than is the opulence of concealed lighting in the mansion from the glittering chandelier. Thus the application of scientific research in all the fields we have mentioned will have immeasurably more effect in the arid areas than in those more favourably situated climatically. Research in rainmaking will benefit both arid and temperate areas, but while in the latter it will merely enable the effect of drought periods to be reduced, in the former its results will be fundamental, bringing about in many of them a change from grazing to cultivation, and in others increasing the fodder available for flocks.

Research in subjects which have a direct bearing on arid zone problems has been and is being carried on in many institutions of a national or local character. Unesco is about to publish a directory listing nearly a hundred

DISTRIBUTION OF ARID ZONES

extremely arid

arid

semi-arid

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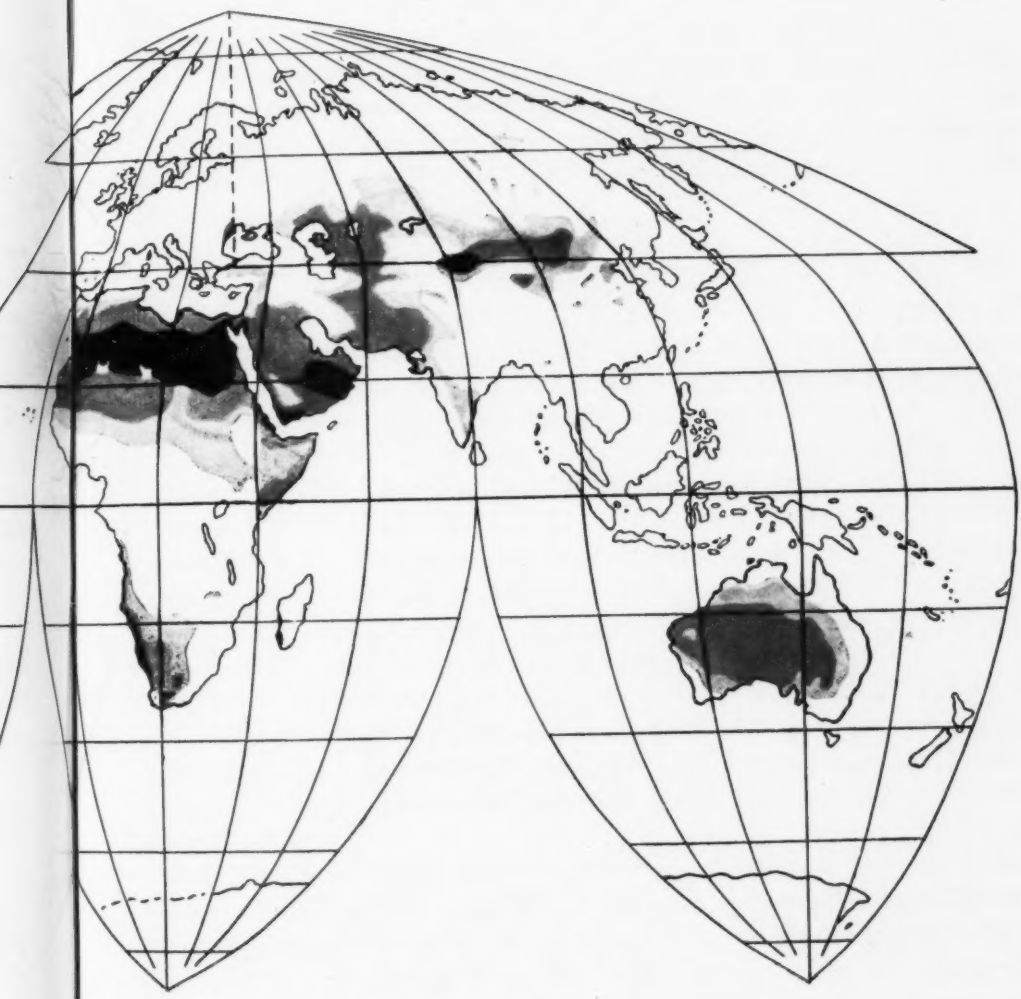

of those that are situated in the territories of its 69 member states. Up till recently there was no official international body operating in the whole field of arid zone research. Such contacts or exchange of information or collaborative programmes as existed depended on personal relations and reading the appropriate scientific literature.

But the desert problem is an urgent one, it is widespread, it is much the same from area to area, and the countries which suffer from it are in the main those that have come to be called the underdeveloped countries. Moreover the deserts are a world responsibility. Putting it at its lowest, everybody everywhere, and more particularly the next generations, will feel, in greater or lesser degree, the effects of desert reclamation. The desert-dweller, crouching now in the cold night air over the miserable bush he has uprooted to burn and warm himself, thereby robbing his animals of future food, will feel the effects directly and personally.

The deserts, then, are an international problem, and Unesco has established an arid zone programme. The object of this programme is to stimulate an awareness in all countries of the arid zone problem, to foster and assist resarch directed to its solution, and to improve the diffusion of the results of research. The programme is conducted under the guidance of an Advisory Committee on Arid Zone Research which has nine members from different countries directly responsible for arid areas either in their metropolitan or overseas territories. The Advisory Committee meets twice a year, to plan and deliberate on the progress of the programme, and to assess the results achieved. Its sessions are attended by representatives of the UN, of the Specialized Agencies interested in the arid zone programme, and of the international non-governmental organizations.

To avoid dispersal of effort, one subject of major importance is chosen for special study each year. Subjects so far dealt with have been hydrology, particularly that of underground water, and plant ecology. This year's subject is arid zone energy sources and their use. Next year it will be human and animal ecology.

The year's work begins with a review by the Advisory Committee of the aspects of the subject to which attention needs to be devoted. Reports reviewing the research which has been carried out on these aspects are then commissioned. When they have been prepared, the reports are considered by the Committee in session, and are subsequently published. A panel of honorary consultants is available to assist with advice and comments on the work in the year's subject, and a survey is made of research being carried out on the subject in different institutions.

This activity leads up to a symposium which is organized jointly by Unesco and a member state which has a large arid area within its frontiers. The member state invites specialists who are its own nationals, with representa-

tives from other countries in the same arid region. Unesco invites scientists from outside the region. The organization of the symposium is the joint responsibility of an organizing group in the co-operating state and the secretariat of Unesco, following the guidance of the Advisory Committee which establishes the programme of the symposium. Thus the arid countries are brought directly into the activities of the programme, their particular problems are underlined in the discussions, and the advice of international specialists is made available.

There is an annual sum available under the programme for the assistance of research projects and international scientific meetings. The Advisory Committee gives preference in recommending projects for assistance from this fund to those that are related to the subject of the year, but projects in other fields, if sufficiently promising, can win the Committee's support. An example will show the type of research project which is helped by the Advisory Committee, and the results attained. About a year ago the Committee considered an application for assistance for a study of the role of dew in plant growth from Dr. F. Went of the Earhart Plant Research Laboratories of the California Institute of Technology. There are many areas of deficient rainfall, especially along the coasts, where dew is relatively heavy, and a knowledge of the use made of it by plants is of considerable importance. The Advisory Committee recommended that the Director-General of Unesco grant the small sum required. In February of this year Dr. Went reported on the preliminary results of his work, carried out in collaboration with an Israeli scientist, Dr. S. Duvdevani. Using common garden plants, such as peas, tomatoes and pumpkins, the capacity of these plants to absorb artificial dew had been measured. Not only were they able to take in the moisture through their leaves and use it for growth, but they could draw it down to their roots and excrete it into the ground, there to be stored for later use. So promising, indeed, were these preliminary results that Dr. Went has been awarded by an American fund a research grant 40 times that of Unesco's original contribution to continue and extend his investigation.

In addition to the activities associated with the subject for the year, the Advisory Committee on Arid Zone Research has undertaken a number of other, general projects. Maps showing those parts of the world which have similar climatic conditions of aridity have been prepared. The usefulness of such maps, apart from their delineation of the extremely arid, arid and semi-arid parts of the world's surface, is that they show which areas should be roughly similar to each other for crop production. For lack of adequate meteorological data the maps are to some extent approximative. The ideal would be to have large-scale maps showing in detail the varying conditions in all the dry parts of the earth. It will only be possible to achieve this when stations recording observations are multiplied in the arid areas.

A proposal to which the Advisory Committee has given attention recently is to prepare a handbook for the assistance of those who plan, direct and carry out the development of arid lands. The collection of certain basic data is essential before such work can be undertaken, and the complex interaction of the many factors involved necessitates research in many widely different fields, between which a careful balance has to be maintained. The project has now reached the stage where an editor has been nominated. Studies will be made in 1954, the book will be written during the following year and published in 1956.

One of the most important achievements of the arid zone programme has been the steadily increasing number of requests received by Unesco from its member states for technical assistance for research projects related to arid zone development. This means that more and more of the "underdeveloped" countries are coming to realize their obligation to improve the living conditions in their desert and near desert areas, and also that the key to the solution of these problems is research and the training of local personnel in scientific techniques and development. And here again, in addition to the operations of the expanded programme of technical assistance, the arid zone programme can help by its co-ordinated allocation of research fellowships in arid zone subjects and by its scheme for the association of research institutions with the programme. These associated institutions agree to make their laboratories available to fellowship holders and workers from other countries, they pool the results of their work, and they agree to give sympathetic consideration to requests which may be made to them by the Advisory Committee to undertake particular pieces of research coming within a co-ordinated programme.

The *Proceedings of the Symposium on the Conquest of the Desert,* which was organized by the Research Council of Israel in co-operation with Unesco last May, is probably the most comprehensive review of the desert problem so far published, containing 50 contributions from scientists who have devoted their life's work to the study of deserts. There was one point in this book that particularly caught my attention. In his introductory lecture on "Potentialities and Problems of Arid Soils", Dr. C. E. Kellogg has a section on social management of arid soils which hints at a big political and social problem in the organization and exploitation of reclaimed areas. To return to the simile of the poor labourer and the rich man as expressing the relations between arid and temperate areas, one can see that in Europe and a great part of North America, the farmer can take considerable liberties with his land—he has, as it were, a bank balance that enables him to afford to experiment, to make mistakes, even to be lazy. Moreover, he can make his own decisions; he can decide to plough or graze, to grow sugar-beet or wheat, to raise pigs or poultry. In an irrigated development area this liberty

does not exist; the equilibrium between the desert and the sown is too delicate and too easily upset. Decisions cannot be left to the farmer, for the very existence of farming depends on decisions taken outside the farm. "For most practical results," says Dr. Kellogg, "irrigation, drainage, torrent and flood control, power development, and perhaps navigation must be provided for within one general scheme. Highly competent engineering and scientific services are necessary to appraise soil and water conditions, to build the works and to maintain the system. A central water master whose decisions are respected is necessary to control the water in accordance with the supplies, and with the competing claims for it within a prescribed framework of rights and priorities."

These irrigation and other reclamation works are costly and the tendency is for more and more of them to be undertaken by the state, which alone has the necessary funds and powers. A government having such far-reaching control over the lives and work-patterns of big sections of its population needs to be strong, wise and respected. To administer its decisions it has need of stable, competent and honest civil servants. And the workers themselves need to be intelligent and educated, not mistaking decisions taken for the good of the community as compulsion requiring servility, knowing how to subordinate personal desires to the public good, and being skilled in intelligent co-operation.

Do these conditions exist in governments and people in the areas that would benefit from solution of the problems of aridity which we have discussed? They must, if the work of the scientists and technicians towards the solution is to be crowned with success. In North Africa and the Middle East are to be found the remains of old civilizations, whose prosperity depended upon irrigation. With the collapse of these civilizations the land returned to desert, worse in many cases than it was before development took place. What caused that collapse—bad government, unworthy people, pestilence, war? Whatever the causes in the past, we must be prepared now to battle as hard against all of them as we do against aridity itself. And in international co-operation we have the means to fight. It is for the peoples of the world to use them.

REPORTS AND DOCUMENTS

SURVEY OF NATIONAL RESEARCH COUNCILS FOR PURE AND APPLIED SCIENCE IN THE MEMBER STATES OF UNESCO

The Unesco Secretariat has frequently been asked, either directly or through its Field Science Co-operation officers, to advise the governments of certain member states on the setting up of a national council for the promotion of scientific research. In the course of complying with these requests, it became evident that information concerning the administrative structure of many of the existing national research councils was not easily available except upon direct application to the research council in question.

At the Seventh Session of the Unesco General Conference, held in Paris in 1952, the Director-General was authorized "to establish an International Advisory Committee on Scientific Research with a view to promoting international co-operation between the national councils and centres of scientific and technical research in fields of common interest" (resolution 2.214), and it became necessary for the secretariat to make contact with existing national research councils. Steps were therefore taken at the same time to collect, through the National Commissions, as much information as possible (in the form of statutes and annual reports) concerning these national councils for scientific and industrial research. On the basis of the material received, a questionnaire was subsequently drawn up and sent direct or through the Unesco Field Science Co-operation officers to national research councils in the member states.

The present study is an analysis of a survey (NS/107) which is based on the replies received to the questionnaire and which was undertaken to serve two main purposes: (a) to provide background information in connexion with the project of establishing an International Advisory Committee on Scientific Research, and (b) to collect reference material for the possible use of persons asked to advise on the setting up of a new research council.

The study covers national research councils for pure and applied science only. While in many countries research in medicine and agriculture is included under these headings, in others separate councils have been established to cover these fields. These special agencies for medicine and agriculture are not included.

INTRODUCTION

The twentieth century has witnessed a profound change in the attitude of governments towards science as well as in the character of science itself. During the last 50 years scientific research has ceased to be the prerogative of individuals working in isolation or in groups divorced from the social and economic problems of their environment. Two world wars, with their urgent problems demanding immediate solution, have accelerated the change in the character of science from an individual to a collective basis, and have forced many governments to an acute realization of their dependence upon

science and scientists, not only for the standard of living but for the ultimate survival of their countries.

If governments depend upon science, it is equally true to say that science today depends to an ever-increasing extent upon the support of governments, for no longer can private enterprise and endowments finance entirely the large-scale research projects which this modern technical age demands. Nor in many countries can universities continue to finance from their diminishing incomes their expanding scientific departments and constantly growing demands for personnel and equipment.

The improvement of the health and well-being of a nation, together with the provision of security, are among the primary functions of a modern government. The encouragement of scientific research of importance to the development of medicine, agriculture, industry and defence, has thus become the concern of the state in most of the scientifically developed countries of the world.

Together with the encouragement and promotion of research in the above fields, goes the need for general co-ordination of a nation's research activities in the different administrative spheres in which research is conducted, namely in the universities, in industry and in the government service itself. With a world shortage of scientists, few governments today can afford to allow the scientific activities of their countries to proceed in a haphazard fashion, resulting in wastage of manpower and unnecessary duplication of scientific effort. The general co-ordination of research activities is thus added to the government's function as a patron of research.

The organizations or agencies employed by governments to assist them in their task of promotion and co-ordination of research, frequently referred to as Research Councils, represent the most modern development of the relations between scientific workers and the government. Since the foundation in 1916 of the first research councils, the Advisory Council for Scientific and Industrial Research in the United Kingdom with the corresponding Department of Scientific and Industrial Research, and the National Research Council in the United States of America, 28[1] countries (see table) have established some form of central agency or group of agencies of the kind for the promotion of research in the different fields of science.

The structure of these agencies varies greatly, being determined in many cases by the past history of the scientific institutions of a particular country and influenced by the nature of the university and higher educational systems, by the presence or absence of private funds and endowments for research, the degree of industrialization of the country and the constitution of the government itself.

Whatever the means employed by these different agencies for the administration of the funds placed at their disposal by the government for the promotion of scientific research, there is present the fundamental consideration of maintaining the correct relationship between the government and the scientist. The scientist needs to be assured that the traditional environment for research—freedom to select his own research projects, continuity of employment, freedom of communication and publication—will be preserved. The government needs to be assured that the money advanced for

1. Particulars of the Academy of Science in Austria and the Council of the Academies of the Federal Republic of Yugoslavia are included in this survey since they perform some of the functions of a national research council in these countries.

research will be used in the best interests of the country as a whole. The constitution of the governing bodies of these agencies is thus of fundamental importance as is also the position of the agency in the scale of government administration.

ANALYSIS OF REPLIES TO QUESTIONNAIRE

This comparative study of the structure and organization of national research councils for pure and applied science, in the member states of Unesco, is based chiefly on the replies received to a questionnaire (see document NS/107) from the following organizations of the countries listed below:[1]

ARGENTINA. National Council for Technical and Scientific Research.

AUSTRALIA. Commonwealth Scientific and Industrial Research Organization (CSIRO).

AUSTRIA. The Austrian Academy of Science.

BELGIUM. National Fund for Scientific Research (FNRS); Institute for the Promotion of Scientific Research in Industry and Agriculture (IRSIA); Institute for Scientific Research in Central Africa (IRSAC).

BRAZIL. National Research Council (CNPq).

CANADA. National Research Council of Canada.

DENMARK. General State Science Foundation; The Technical-Scientific Research Council.

EGYPT. Fouad 1st National Research Council.

FRANCE. National Centre for Scientific Research (CNRS); Overseas Scientific Research Bureau (ORSOM).

GERMANY. German Research Association.

INDIA. Council of Scientific and Industrial Research (CSIR).

INDONESIA. National Council for Sciences.

ISRAEL. Research Council of Israel.

ITALY. The National Research Council (CNR).

JAPAN. Science Council of Japan (JSC).

MEXICO. National Institute for Scientific Research (INIC).

NETHERLANDS. Netherlands Organization for Pure Research (ZWO); Central National Council for Applied Scientific Research in the Netherlands (TNO).

NEW ZEALAND. Council of Scientific and Industrial Research (CSIR); Department of Scientific and Industrial Research.

NORWAY. Norwegian Council for Scientific and Industrial Research (material supplied by National Commission); Norwegian Research Council for Science and the Humanities (NAVF).

PAKISTAN. Department of Scientific and Industrial Research.

PHILIPPINES. National Research Council of the Philippines (NRC).

SPAIN. Higher Council for Scientific Research (CSIC).

SWEDEN. Swedish Natural Science Research Council (NFR); State Council of Technical Research (TFR).

SWITZERLAND. Swiss National Fund for Scientific Research.

UNION OF SOUTH AFRICA. The South African Council for Scientific and Industrial Research (SACSIR).

1. The names of these organizations are given in their original language in the table appended at the end of this study.

UNITED KINGDOM. Department of Scientific and Industrial Research (DSIR).
UNITED STATES OF AMERICA. National Science Foundation (NSF); National Academy of Sciences-National Research Council (NAS-NRC).
YUGOSLAVIA. Council of Academies of the Yugoslav People's Federal Republic.

In preparing the analysis, use has also been made of a series of reports on *Science and Government* commissioned by Unesco from individual scientists in 11 different countries, and of a report on the national organization of research which was prepared as a result of discussions at the British Commonwealth Scientific Conference held in Australia in 1952 (Report of Proceedings, pp. 34-36).

For the sake of brevity, in the following analysis the name of the country only is used to stand for the national research council, except in those cases where there is more than one such organization in the same country and it is necessary to distinguish between them.

I. GENERAL DEFINITION

For the purpose of this study a research council may be defined as a government sponsored agency for the promotion and co-ordination of pure and/or applied research on a national scale. The council may be purely advisory or it may itself administer funds placed at its disposal by the government. In some cases, it may combine one or both of these activities with the conduct of research in its own laboratories. Some agencies depend entirely upon the funds provided by the government, while others have additional sources of revenue.

II. GENERAL FUNCTIONS OF A NATIONAL RESEARCH COUNCIL

1. The principal aim of a national research council, in scientifically advanced countries, is the encouragement of both fundamental and applied research, and more specifically the encouragement or carrying out of scientific research which is of importance to the development, in the national interest, of industry, agriculture and medicine. In some cases, the national research council encourages or undertakes research also in the sphere of the humanities (see III, 4).

2. In countries which are less highly-developed scientifically, the chief function of the research council is not so much to encourage or carry out scientific research work itself, as to organize means whereby the results of scientific research conducted in more scientifically advanced countries may be made available and adapted to the solution of the particular problems of the country concerned. This may involve as first priorities the creation of documentation centres of national and foreign scientific literature and the provision of fellowships for the training of research workers at home and abroad.

3. In all cases, the primary functions of a research council are first to assess the overall scientific activity of the country and appraise the scientific potentialities and needs in the different economic and administrative spheres; then to encourage or conduct research work which will supplement the

efforts of particular groups and so fill the gaps in the nation's research activities.

III. SCOPE OF RESEARCH COUNCILS

1. A number of countries have established separate agencies for medical and agricultural research.[1] These separate agencies are not included in the survey. In some countries a group of councils, each with a separate budget, has been set up to deal with different subjects (notably in *Belgium, Netherlands, Norway, Sweden*) or separate councils have been appointed for pure and applied research (see paragraph 2), while in other countries the research council may cover every branch of science including the humanities (see paragraph 4). There are also, in a number of countries, centres of research which play similar roles to the research councils in different fields of science, but which are not designated as such.

2. Separate research councils for pure and applied science have been established in the following countries: *Belgium, Denmark, Netherlands, Norway, Sweden.*

One advantage claimed for separate councils for pure and applied research is that, with separate budgets, administered by different specialists in each case, there is no danger that applied science, which is more costly than pure research, will encroach on the funds which should be allocated to the latter. This situation can occur, especially in times of pressure for quick results, when these two branches of research are financed from the same fund.

A further consideration in support of separate councils is the different environments which favour pure and applied research. The former thrives best in a university atmosphere, whereas applied research can be satisfactorily carried out in a government laboratory. The difference in the structures of the separate councils for applied and pure research is perhaps most marked in the *Netherlands* (see The Netherlands Organization for Pure Research, ZWO; and the Central National Council for Applied Scientific Research in the Netherlands, TNO). In this case, provision is made in the constitution of their governing bodies for close co-operation between the two organizations.

In spite of the above considerations, however, in some countries there is thought to be a danger in creating or perpetuating a gulf between pure and applied research, which are two complementary activities mutually dependent on each other. One task of a research council is to ensure that discoveries in pure science which may be capable of industrial application are not overlooked, and this task is rendered less difficult if there is one organization to ensure the necessary co-ordination. In *France*, pure and applied science were originally under two distinct organizations: the Caisse Nationale de la Recherche Scientifique and the Centre National de la Recherche Scientifique Appliquée, until their fusion under one establishment, the Centre

1. Separate organizations exist for medical research in *Australia, France, India, New Zealand, Sweden, United Kingdom,* and for agricultural research in *Belgium, France, Germany, Italy, Netherlands* and *United Kingdom.* These are organizations distinct from the relevant government ministries.

National de la Recherche Scientifique (CNRS), in 1939. The CNRS today endeavours to develop scientific research in all its aspects, it being considered that these aspects are interdependent and should proceed in the closest possible liaison.

3. The results of research in physical sciences, biology and medicine frequently give rise to new social problems, and to stimulate scientific research while ignoring the social consequences can only contribute to increasing the maladjustment of man to his environment, which is one of the problems of this scientific age. Research councils in the following countries include the social sciences as well as natural sciences in their programmes: *France* (CNRS), *Germany, Japan, Netherlands* (ZWO), *Norway* (NAVF), *South Africa, Spain, United Kingdom.*

The inclusion of natural and social sciences under the same organization enables close co-operation between natural and social scientists to be maintained at all stages of investigations and may afford the possibility of solving problems as they arise.

In other countries, social science problems are frequently dealt with by other government departments, private agencies or by a separate research council (e.g. *Sweden*).

4. The idea of science and the humanities being treated under one organization is familiar in the case of most of the continental academies founded in the seventeenth and eighteenth centuries, and this idea has been preserved in a few of the national research councils, e.g. *France* (CNRS), *Germany, Japan, Netherlands* (ZWO), *Norway* (NAVF), *Spain.* The *Austrian* Academy of Sciences and the Council of Academies of the *Yugoslav* Peoples Federal Republic also cover both fields.

Although from the point of view of finance and co-ordination these two fields of human activity demand different treatment, it is considered in some cases important that encouragement of research in these two disciplines should go hand in hand. There is a growing concern in some countries at the concentration and support of the physical sciences in universities to the exclusion of the humanities, and it is considered undesirable that this state of inequality between the scientific and humanistic disciplines should be continued and emphasized in post-graduate life by the research councils.

IV. CONSTITUTION OF COUNCILS AND AUTHORITIES RESPONSIBLE FOR SCIENTIFIC POLICY

1. The body responsible for the broad lines of scientific policy is in some cases the council itself, e.g. such councils as *Israel, Japan, Netherlands* (ZWO), *Norway* (NAVF), *South Africa,* etc.

In other cases, there is an advisory council which advises the organization concerned.

In *New Zealand,* the policy of the DSIR is determined by the Minister of Scientific and Industrial Research on the advice of an Advisory Committee. In *Australia,* the power to determine scientific policy is in the hands of an Executive, advised by an Advisory Council. Constitutionally, the DSIR, *United Kingdom,* is controlled by a Committee of the Privy Council for scientific and industrial research which consists of the Lord President (a Minister of State with a seat in the Cabinet) and seven *ex officio* ministerial

representatives. In practice, however, the Lord President acts for the Committee on the advice of an Advisory Committee. In *India,* the policy of the CSIR is determined by a governing body of which the Prime Minister is president. The governing body is advised in technical matters by a Board of Scientific and Industrial Research.

2. The composition of these councils or advisory bodies which determine scientific policy is naturally of great importance, as is also the method adopted for the selection of members where the composition is not solely by representation of definite organizations. It is generally agreed that the composition should be predominantly scientific.

3. Before examining the constitution of the various councils and advisory bodies, a distinction must first be made between those research councils in which the appointments to membership are made: (a) by the government, or (b) independently of the government.

4. The majority of research councils included in this survey belong to the first group.

Exceptions are:

(a) the *U.S.A.* National Research Council, whose membership is determined by the National Academy of Sciences (representatives of the government executive agencies are appointed with the approval of the President of the United States of America);

(b) the National Research Council of the *Philippines,* whose membership, apart from the original charter-members appointed by the president of the country, is determined by the Council itself;

(c) the Science Council of *Japan,* whose members are elected by a limited electorate of qualified scientists from among the whole scientific population;

(d) the Fonds National de la Recherche Scientifique, *Belgium,* whose Conseil d'Administration is composed of certain *ex officio* administrators and 14 delegates nominated by the Conseil d'Administration of the Fondation Universitaire;

(e) the *German* Research Association, which is composed of 41 corporate members whose representatives form the General Assembly. The latter elects the 27 scientists who form the Senate (the body responsible for scientific policy) and who are also members of the Governing Board;

(f) the Council of the Fonds National *Suisse* de la Recherche Scientifique, which is composed of representatives of relevant educational, scientific, federal and cantonal organizations, who appoint their own representatives;

(g) the Plenary Council of the CSIC, *Spain,* a representative body which elects its own Executive Board.

5. Some variety is shown in the degree of flexibility allowed for in the constitution of those research councils where the appointments to membership of the council itself or of the authority responsible for scientific policy are made by the government.[1] Broadly speaking, there are four main categories:

(a) where the composition is determined by *ex officio* governmental appointments and stipulated representation, e.g. *Argentina;*

(b) where the composition is determined by stipulated representation, e.g. *Norway* (NAVF), and *Denmark* (General State Science Foundation);

1. The government's part in the actual appointment of the members is often a mere formality.

(c) where the composition is determined partly by stipulated representation with allowance made for the appointment of experts outside the organizations represented, e.g. *Brazil, India, Italy, Israel, Netherlands, Pakistan, Sweden* (NFR);

(d) where the membership is made up of experts chosen in their individual capacity and not as representatives of particular organizations, e.g. *Canada, Egypt, France* (CNRS), *Mexico, Union of South Africa, United Kingdom, United States of America* (National Science Foundation).

6. Where experts are appointed in their individual capacity and not as representatives of specified organizations, the choice in the method adopted for their selection and nomination may rest primarily with the scientists or with the government: e.g. nominations to membership of the Comité National de la Recherche Scientifique (*France*) are made on the recommendation of the Director of the CNRS and of a special electoral body composed of university staff and scientists including members of the research staff of the CNRS itself. The scientific experts of the Conselho Nacional de Pesquisas (*Brazil*) are chosen from a list prepared by the Executive Board of CNPq. The experts chosen to serve on the Advisory Council of the DSIR (*United Kingdom*) are appointed after consultation with the President of the Royal Society. The National Science Board of the National Science Foundation (*United States of America*) is appointed by the President by and with the advice and consent of the Senate, etc.

7. In addition to the council itself or to the main advisory committee on scientific policy, many research councils have established, as a permanent feature of their constitution, scientific and/or technical committees on special subjects. These committees advise on matters within their particular sphere and in many cases make recommendations concerning the applications received for research grants (e.g. *Australia, Denmark, France, Germany, India, Israel, Netherlands, New Zealand, Norway, Pakistan, Switzerland, United Kingdom, United States of America*).

V. RELATION TO GOVERNMENT ADMINISTRATION

1. The table shows how the research councils in the various countries are related to government administration. While many of them enjoy scientific and in some cases financial autonomy, the majority of them are placed for administrative purposes within the framework of one of the administrative ministerial departments.

2. In some countries, however, the research council has been placed outside the administrative control of any one government department. The National Science Foundation (*United States of America*), CNPq (*Brazil*) and INIC (*Mexico*) are directly responsible to the President of the country. The research councils in *Israel, Italy* and *Japan* are responsible to the Prime Minister, in *Egypt* to the Council of Ministers, in the *United Kingdom* to the Lord President of the Council (see IV, 1) and in *Canada* to a Committee of the Privy Council. In *Australia* and *New Zealand* the research councils are under a special Minister of Scientific and Industrial Research.

3. There are considered to be both practical and scientific reasons in favour of placing a research council as high as possible in the scale of

government administration and outside the control of any one government department:

(a) the research council's task of assessing the overall picture of scientific activity and assigning priorities in research projects is facilitated by ready access at the highest level to all relevant information;
(b) the research council can better serve the needs of the government service as a whole if it is freed from the pressure of the immediate interests of any one particular administrative department;
(c) the planning of long-term research is only possible if the research council is exempt from the responsibility of executing particular policies of administration concerning health, agriculture and industry, etc. to which the relevant ministries may be committed;
(d) contact with other ministries and government services, universities and industry is facilitated to the extent that bureaucratic control is minimized;
(e) the usual conditions of government service are not always the most suitable for obtaining the best results in scientific research, and in a separate organization, outside the control of any one government department, scientists can create their own environment.

4. The increasing importance of science in every aspect of national life merits the full-time attention of the Minister who is responsible for it to the government and it is considered in some cases that the appointment of a special Minister for Scientific and Industrial Research, as has been done in *Australia* and *New Zealand,* has much to commend it. It can happen that the placing of a research council under a Minister of State can defeat its own end if the Minister concerned should be too greatly burdened with other affairs of more pressing urgency.

VI. SOURCES OF REVENUE

1. The main source of revenue of most of the research councils is an annual subvention from the government voted on the national budget or on the budget of the appropriate ministry to which the council is affiliated (exception: NAS-NRC, *United States of America*). This is augmented in some cases by private donations and bequests or by contributions from industry for special work. While in some countries it is considered that stability of funds over a long period or for a term of several years is essential in order that long-range programmes may be carried out, in others it is considered preferable, in view of the changing nature of scientific development and fluctuating cost of living, to present the budget to the government each year. In most cases, according to usual governmental practice, monies appropiated on one year's budget may not be carried over to the next year (ZWO, *Netherlands* is one of the exceptions).

2. The budget of the recently founded *Swiss* National Foundation is not decided within the annual budget of the government but has been fixed once and for all by a decree of parliament. The Foundation is in this way free from political and economic fluctuations.

The FNRS (*Belgium*) obtains its income from interest on the original capital, provided by contributions from banks, industry, commerce and private individuals on its creation in 1928, as well as a state grant made in accordance with an enactment of 23 April 1949. The limit of the money

to be appropriated to the National Science Foundation (*United States of America*) out of the Treasury was fixed in the act of its establishment. The Foundation also receives transfers of appropriated funds from other federal agencies and is entitled to receive funds from private sources.

3. The TNO Organization (*Netherlands*), in addition to a considerable yearly subvention from the government, receives subsidies from industry and payment for services rendered. Some TNO centres through their activities in this direction have become practically if not entirely self-supporting.

Other research councils which are partly supported by industry as well as the government are: *Germany, Israel, Mexico, Spain, Australia* and *Denmark* (TSRC).

4. An original source of revenue is that of the research councils in *Norway* which, since 1949, have been financed largely from the profits of the football pools. A Special Joint Committee of the research councils established in 1949 has the task of making recommendations to the Ministry of Ecclesiastical Affairs and Education respecting the portion of the profits of A/S Norsk Tipping which should be devoted to research, and of allocating the money received among the different research councils.

5. In some countries private donations for research are encouraged by allowing the deduction of the amounts donated in the declarations of income for the purpose of taxation assessment.

VII. THE ESTABLISHMENT OF LABORATORIES UNDER THE AUSPICES OF THE RESEARCH COUNCIL

1. In some countries the general policy of the research council is to support research in universities and existing institutions and/or to encourage the setting up of new laboratories by outside agencies, while in other countries the research councils construct and maintain their own laboratories (see table). In many cases a combination of these arrangements is employed by the same research council.

2. Many of the older established research councils, which today maintain laboratories of their own, started as agencies for the distribution of government funds in support of research in existing institutions, or took over laboratories already in government service. For example, the NRC (*Canada*), started as a grant-giving body in 1917 and 10 years later was empowered to operate its own laboratories. The CNRS (*France*), originated from the Caisse des Recherches Scientifiques created in 1901 for supplying grants to existing laboratories for equipment. In the *United Kingdom* and *New Zealand*, the nuclei of the Departments of Scientific and Industrial Research, when originally established, in 1916 and 1926 respectively, were formed by the transfer of existing services and laboratories from other departments. The construction of new laboratories came later. In *Australia*, the CSIR followed an earlier organization, the Institute of Science and Industry, which operated mainly through the organization of research in universities, etc.

3. The construction or sponsoring of new laboratories by a research council is sometimes only undertaken in those cases where very large or expensive equipment is needed (such as nuclear physics) for which the facilities offered by existing institutions are inadequate [e.g. ZWO (*Netherlands*)]. In other cases, the existing scientific institutions may be altogether

insufficient to meet the needs of a nation which is rapidly evolving scientifically (e.g. *India, Union of South Africa*) and construction of national laboratories on a larger scale becomes necessary.

4. Where existing scientific facilities in a country are inadequate and necessitate the building of new laboratories by the research council, there is sometimes an initial period of difficulty concerning the distribution of scientific manpower between the universities and the new laboratories. If the facilities for research and the salaries offered by the research council compare favourably with those in the universities, there may be a draining of teaching staff and potential research graduates from the universities, to the scientific detriment of the latter. This may be mitigated to some extent by the appointment of foreign professors to university posts in the interim period until new graduates are trained. The situation is usually temporary, since the establishment of new laboratories by the research council, in setting a high standard of research, can be a source of inspiration to the scientists of the country, and, by creating a demand for research workers, can encourage an increased flow of new students to the science faculties of the universities.

5. While there is no clear-cut demarcation of the boundary between pure and applied research, both being interdependent, the general policy of most research councils which maintain research establishments of their own is to concentrate more on applied research in their own laboratories while supporting fundamental research in the universities and outside institutions (see VIII). It is generally recognized, however, that a certain proportion of the work in national laboratories should be creative and of high intellectual interest to maintain the scientific standard and morale of the research workers.

6. The importance of maintaining the closest contact between the research council laboratories and those of the universities: (a) in order that the discoveries being made in fundamental science may be followed and applied where appropriate to the solution of industrial problems, and (b) to ensure, by an interchange of research workers, the flow of new ideas necessary for creative work has prompted some research councils to set up their laboratories in close proximity to the universities, sometimes in the same building, or to form joint laboratories with the universities.

In others, the structure of the research council is based on a free interchange of their research workers with the personnel of the universities [e.g. CNRS (*France*), where the salary scales in the two cases are integrated; *Italy,* where most of the research workers in the study centres depending on the CNR are also university teachers; *Spain,* where the CSIC maintains research centres in the universities].

In this connexion may be mentioned also the system adopted by the NRC of *Canada* of awarding post-doctorate fellowships tenable in their laboratories for one year, which ensures a constant inflow of new university personnel.

VIII. RESEARCH SPONSORED IN UNIVERSITIES AND OUTSIDE INSTITUTIONS

1. In distributing the funds placed at the disposal of research councils for the promotion of research outside their laboratories, there are three main aspects to be considered:

(a) the training of research workers, encouraged by the award of scholarships and research grants for study and specialization at home and abroad;
(b) the stimulation of fundamental research irrespective of immediate or practical results;
(c) the sponsoring of research in certain specified fields or for the solution of definite problems.

In making the awards, the policy of the council may be to support: (a) individuals; (b) institutions; (c) projects.

2. Government support of research projects in universities without endangering the academic freedom of these institutions is a subject which occupies the minds of scientists of most countries to a greater or lesser extent. Government control is minimized in many cases by the policy of basing support on proposals for research initiated by the scientists or institutions themselves, i.e. on the basis of applications received by the research councils. This is notably the case with those councils which specialize in supporting pure research, e.g. *Belgium, Denmark, France, Germany, Netherlands, Sweden, Switzerland,* etc.

3. Some research councils in addition adopt the policy of supporting fundamental research at universities in those subjects in which they are particularly interested or for studies in disciplines that are short of trained men and women (e.g. *Australia, United Kingdom,* etc.), the initiative in this case coming from the research council in the form of fellowships offered in certain prescribed subjects.

4. The position is more complicated where the research sponsored by the government is of the type which demands the solution of definite problems: these problems, encountered in industry or elsewhere, may be solved by means of applied research or sometimes by further fundamental research. In most cases sponsored research of this type is short-term, and the emphasis on the need to produce tangible and practical results is alien to the usual university conception of pure basic research. In such cases, it is however generally considered preferable to leave the internal control of policy, personnel and methods employed for conducting the research in question entirely to the university authorities themselves.

5. There are considered to be both advantages and disadvantages in government-sponsored applied research being conducted in universities. A certain amount of sponsored applied research is a valuable stimulant and provides opportunities for the specialized training of research graduates, e.g. *Belgium* (IRSIA), *Sweden* (TFR), etc.

There is, however, the potential danger that, if developed on too large a scale, applied research may deflect university teachers from their educational activities, not the least important of which is the guiding of research graduates in the ways of fundamental research. Research students also may be hindered from following their special aptitudes if recruited too early for the investigation of projects undertaken by their departments for the government.

The bulky equipment necessitated by some types of applied research and the additional technical assistants and workmen needed may present problems of space and administration in some academic institutions. In some universities of the *United States of America,* where there is a large volume of contract research from government and industry, it has been found desirable to set up special administrative offices to deal with these problems.

6. A number of research councils assist research in universities and other institutions by awarding grants for the purchase of special equipment, usually of the kind which the institution could not be expected to purchase from its normal budget. Grants for the employment of junior helpers are also usual.

IX. PROMOTION OF RESEARCH IN INDUSTRY

1. In the more industrialized countries, the part played by the research councils in the promotion of research in industry is sometimes only a small fraction of the government's total contribution to industrial research. The magnitude of the field and the multiplicity of methods for organizing co-operation and co-ordination in scientific and industrial research render the subject far beyond the scope of this survey.

2. In addition to carrying out applied research in their own laboratories and to sponsoring research in universities, there is, however, another way in which many of the research councils promote research in industry, i.e. by the system of Co-operative Research Associations. This system originally sponsored by the Department of Scientific and Industrial Research (*United Kingdom*) has been adopted, with suitable modifications, by research councils in several countries, e.g. *Australia, Germany, Israel, Italy, New Zealand, South Africa,* and *Sweden*. A research association of this kind is an autonomous body formed to serve the scientific and technical needs of a particular industry. It may be financed by the industry itself or by the industry with the assistance of grants from the government related in amount to the sums raised by the industry. This method is considered to be most applicable in industries where there is a large number of separately constituted factories.

3. There are various other ways in which research councils co-operate with industry in the carrying out of research. For example, in certain laboratories under the CNRS (*France*) applied research is carried out in liaison with professional groups. This method of assisting industry is considered to be most applicable for long-term projects involving the creation of new processes. The work which is carried out under the direction of a member of the CNRS is performed by the personnel of the trade group concerned, which pays them and bears the cost of their research.

The TNO Organization (*Netherlands*) is a unique example of co-operation between science, industry and government. In the research institutes under its control, in addition to conducting a programme of free research (approved by the Council), contract research work is undertaken for individual firms or groups of co-operating firms, which in some cases may render them almost financially independent.

5. In most countries there is the problem, to a greater or lesser extent, of getting the results of successful research applied by industry with the least delay. While this depends ultimately on an adequate number of technically trained people in positions of authority in industry and is thus fundamentally an educational matter, it depends also on due recognition of the value of applied research in industrial development among the manufacturers and workers themselves. Some research councils maintain services of an informative or educational nature for the benefit of industry, and by means of suitable publicity (such as participation in trade exhibitions, publications,

industrial films and the organization of conferences, etc.) stimulate interest in the application of the results of research among trade organizations.

X. SCIENTIFIC PUBLISHING

It is considered in some countries that an important phase of scientific activity requiring government support is that of publication of the results of current research. The increased number of research workers, resulting in a greater number of papers being read before learned societies and, in some countries, the releasing for publication of the results of secret research undertaken during the war, have strained to the limit the capacities of many of the existing publishing organizations at a time when publishing costs are rising. There is consequently considerable delay in the publication of the results of current research, which is becoming a worldwide problem.

Many research councils support scientific publications, in some cases in addition to maintaining publications of their own. Subventions may be given continuously for the support of scientific periodicals or for the publication of monographs or books of a specialized or restricted interest, e.g. *Austria, Brazil, Denmark* (Science Foundation), *France* (CNRS), *Germany, Italy, Netherlands* (ZWO), *Norway* (NAVF), *Sweden* (NFR).

XI. RESEARCH IN OVERSEAS TERRITORIES

The centres in *Belgium* and *France,* viz. the Institut pour la Recherche en Afrique Centrale and the Office de la Recherche Scientifique de la France d'Outre-Mer, have a somewhat similar structure to the other centres in these countries for the co-ordination of scientific research in different fields. An important aspect of the work of these organizations is the training in the colonies of research workers for the special needs of these territories. In the *United Kingdom,* the government's main contribution to colonial research is made through the provisions of the Colonial Development and Welfare Act. For the co-ordination of the many aspects of research involved in colonial development, the United Kingdom Colonial Office has established a number of committees, the senior one being the Colonial Research Council. This is an advisory committee to the Secretary of State for the Colonies and is in no way similar in structure to the other research councils (e.g. Medical Research Council, Agricultural Council and DSIR). It is not, therefore, included in this survey.

SUMMARY OF MAIN FEATURES OF NATIONAL RESEARCH COUNCILS FOR PURE AND APPLIED SCIENCE

Country	*Research council*	*Date of foundation*[1]	*Nature*	*Responsible or affiliated to*	*Research laboratories under direct control*	*Composition of council and governing bodies*	*Chief types of subvention for research and number per year*
Argentina	Consejo Nacional de Investigaciones Ténicas y Científicas	1951	Governmental, advisory, administrative	Ministry for Technical Questions	No	Council consists of science delegates from each university plus 4 *ex officio* government representatives.	Fellowships.
Australia	Commonwealth Scientific and Industrial Research Organization	1949 (1926)	Governmental, administrative	Minister in charge of organisation	Yes	Executive consists of chairman plus 4 members (3 of which must be scientific). Appointed by Governor-General. Advised by Advisory Council.	Postgraduate scholarships for study and research at home and abroad (30). Grants-in-aid for special investigations.
Austria	Osterreichische Akademie der Wissenschaften	1947 (1847)	Semi-governmental, administrative, advisory	Ministry of Education (administratively)	Yes	Membership of Academy: 66 ordinary members, 160 corresponding members and 24 honorary members.	Fellowships (unspecified, 30). Grants-in-aid for special investigations. Grants for travel and publications.
Belgium	Fonds National de la Recherche Scientifique	1928	Public utility institution	Ministry of Education	No	Council of Administration composed of 28 persons comprising *ex officio* administrators and 14 members nominated by the Fondation Universitaire.	Bursaries for aspirants (18), chargés de recherches (9) and chercheurs qualifiés (6) to perfect their training in research. Grants for (a) associés (5 awards); (b) equipment (55 of varying amounts); (c) miscellaneous, including travel grants.

1. The date in brackets is that of the original organization which gave rise to the existing research council.

Country	*Research council*	*Date of foundation*	*Nature*	*Responsible or affiliated to*	*Research laboratories under direct control*	*Composition of council and governing bodies*	*Chief types of subvention for research and number per year*
	L'Institut pour l'Encouragement de la Recherche Scientifique dans l'Industrie et l'Agriculture	1944	Governmental, administrative (finance)	Ministry of Economic Affairs-Ministry of Agriculture	No	Board of Directors composed of 20 members appointed by the King: 14 proposed by FNRS and 6 by Ministries of Economic Affairs and Agriculture.	Fellowships for study and research. Grants-in-aid of specific scientific and technical research. Travel grants (15-20 per annum).
Brazil	Conselho Nacional de Pesquisas	1951	Autonomous body, governmental, advisory, administrative	President of the Republic	Yes	Executive Board of 25: President and Vice-President (appointed by President of Republic); representatives of 5 ministries, academy, industry, etc., recommended by Executive Board.	Grants to institutions for equipment, publications, research contracts, libraries, etc. (53 in 1951). Fellowships for study or research (68 in 1951).
Canada	National Research Council of Canada	1916	Governmental, administrative	Committee of the Privy Council on Scientific and Industrial Research	Yes	Hon. Advisory Council consists of President, 3 Vice-Presidents (1 admin., 2 scientific), and not more than 17 other members. Appointed by Governor in Council. Executive Committee consists of President and Vice-Presidents and 3 other members selected by the Council.	Fellowships for post-graduate work in Canadian universities and in some cases for study abroad (228 awards in 1952); post-doctorate research fellowships tenable in the National Research Laboratories (75 fellows are holding awards). Grants-in-aid of specific research projects. "Assisted Research Grants" for special equipment and for employment of junior helpers.

Denmark	Statens Almindelige Videnskabs-fond	1952	Govern-mental, autonomous	Ministry of Education	No	Executive Committee advised by 5 specialist commissions whose members are appointed by universities, academy, etc. Executive Committee consists of a member of each commission plus 2 representatives of ministries.	Grants for excavations, expeditions. Grants for equipment, material and assistance. Grants for travel and publications.
	Det Teknisk-Videnskabelige Forsk-ningsraad	1946	Semi-govern-mental,	Prime Minister Department	No	President of Academy of Technical Sciences is *ex officio* chairman of Research Council and includes chairmen of 8 groups of the academy plus 5 members appointed by Prime Minister (2 representing government and others relevant institutions.	Scholarships for study at home and abroad. Grants to individuals for specific researches.
Egypt	Magless Fouad Al-Awal Al-Ahly Lelbohouth	1945	Semi-govern-mental, advisory, administrative	Council of Ministers	Yes	Council composed of 12 members chosen in their individual capacity and nominated in first instance by Royal Decree. Committee of Scientific Research composed of senior members of Council, chairmen of permanent committees and ministerial representatives.	Scholarships for study and research abroad (15 in 1949). Research contracts (7 in 1949).

Country	*Research council*	*Date of foundation*[1]	*Nature*	*Responsible or affiliated to*	*Research laboratories under direct control*	*Composition of council and governing bodies*	*Chief types of subvention for research and number per year*
France	Centre National de la Recherche Scientifique	1939 (1901)	Governmental, advisory administrative, autonomous body (admin.)	Ministry of Education	Yes	Scientific activity determined by Comité National de la Recherche Scientifique composed of 372 scientists and industrialists divided into 31 sections of 12 members each forming 13 groups or disciplines. Appointed by Minister of Education. Proposals executed by directorate of 12 members. CNRS is administered by a Board of Directors (ministerial representatives) and the Director assisted by 2 Assistant Directors.	Bursaries for research workers in French or foreign research establishments. Grants for scientific missions, equipment and research material, and publications.
Federal Republic of Germany	Deutsche Forschungsgemeinschaft	1951 (1920)	Advisory, administrative (finance)	Federal Home Office (Department of Cultural Affairs)	No	Governing Board consists of 54 members: 27 scientists, 22 representatives of Federal Government and ministries of the *Länder*, 5 representatives of industry; scientist members form the Senate. Executive Committee of 24 members (12 scientists and 26 technical committees.	Research grants and fellowships. Grants for travel and publications.
India	Council of Scientific and Indus-	1942	Autonomous body, govern-	Ministry for Natural Resources	Yes	Governing Body of which Prime Minister is President consists of represen-	Research studentships and scholarships. Grants to (a) individuals for

	of Scientific and Industrial Research		body, governmental, advisory, administrative	Natural Resources (admin.), Prime Minister (policy)		Prime Minister is President consists of representatives of ministries, scientists and industrialists. Advised by a Board of Scientific and Industrial Research of 19 members, of whom 9 are eminent scientists. 26 research advisory committees.	scholarships. Grants to (a) individuals for specific researches; (b) institutions for investigation of special problems.
Indonesia	Madjelis Ilmu Pengetahuan Nasional	In process of being constituted	Governmental, advisory,	Ministry of Education, Instruction and Culture	No	Executive Board consists of 9-11 members representing natural and social sciences, appointed by President of the Republic. Advised by Advisory Board of 40 members, appointed by Minister of Education, Instruction and Culture on recommendation of Executive Board.	Grants for publications (other grants not specified).
Israel	The Research Council of Israel	1949	Governmental, advisory, administrative	Prime Minister	Yes	Council composed of 12 members, 7 scientists appointed by Prime Minister and 5 representatives of the scientific institutions. Advisory and *ad hoc* committees for special problems.	Research grants to individuals. Fellowships for study abroad. Travel grants.
Italy	Consiglio Nazionale delle Ricerche	1923	Governmental, autonomous body, administratively	Prime Minister's Office	Yes	Governing Board of 72 members (grouped into 6 committees): 40 elected by universities, 12 experts, 20 government officials. Chairman nominated by President of the Republic. Executive Board composed of chairmen of the 6 groups and administrators.	Scholarships for post-graduate study at home and abroad—awarded by competition. (In 1952, 71 awarded for Italy and 17 for abroad.) Grants to university laboratories for special research projects.

1. The date in brackets is that of the original organization which gave rise to the existing research council.

Country	*Research council*	*Date of foundation*[1]	*Nature*	*Responsible or affiliated to*	*Research laboratories under direct control*	*Composition of council and governing bodies*	*Chief types of subvention for research and number per year*
Japan	Nihon Gakujutsu Kaigi	1949	Autonomous body, advisory	Prime Minister	No	Council composed of 210 members elected by limited electorate of qualified scientists determines policy. Management Committee of 31 members.	Council advises the government ministries on general principles to be followed in making grants and awarding subsidies but has no control over funds.
Mexico	Instituto Nacional de Investigacion Científica	1950	Governmental, advisory, administrative	President of Mexico	Yes	Governing Board of 7 appointed by the President of Mexico.	Fellowships for study at home and abroad (20 per annum).
Netherlands	Nederlandse Organisatie voor Zuiver-Wettenschappelijk Onderzoek	1950 (1946)	Semi-governmental, advisory, administrative (finance)	Ministry of Education, Arts and Sciences	No	Council composed of representatives of universities, Ministry of Education, TNO, plus 5 experts. Appointed by Minister of Education, Arts and Sciences. Board consists of Chairman and Vice-Chairman of Council, the representative of the Minister of Education, Arts and Sciences, plus 4 Council members.	Post-doctorate fellowships for research at home and abroad (about 8 per annum). Grants to institutions and individuals for salary of research workers and assistants and for purchase of equipment (in 1952, 123 awards made). Grants for publications.

	Centrale Organisatie TNO	1930	Co-operative body for state, industry and science, semi-governmental	10 ministries represented on Governing Board	Yes	Boards of the Central Council and Branch Councils are appointed by the Crown. The membership of the Board of the Central Council is nominated half by the Royal Academy of Sciences and half by the Social Economic Board.	None.
New Zealand	Department of Scientific and Industrial Research	1926	Governmental, administrative	Minister in charge of Scientific and Industrial Research	Yes	Council consists of chairman and not more than 8 members appointed by Governor-General. Council and department assisted by 14 specialists committees.	Various national research scholarships for research at home or abroad (9 in all). Bursaries for completion of training. Grants to universities for specific projects to be carried out under supervision of a member of the university staff.
Norway	Norges Teknisk Naturvitenskapelige Forskningsrad	1946	Semi-governmental, advisory, administrative	Ministry of Industry	Yes	Council of 26 members appointed by the King on recommendation of certain ministries, industrial federations, universities and research institutions.	

1. The date in brackets is that of the original organization which gave rise to the existing research council.

Country	*Research council*	*Date of foundation*	*Nature*	*Responsible or affiliated to*	*Research laboratories under direct control*	*Composition of council and governing bodies*	*Chief types of subvention for research and number per year*
	Norges Almenviten-skapelige Forskningsrad	1949	Semi-govern-mental	Ministry of Ecclesiastical Affairs and Education	Yes	Council of 32 members (divided in 5 working groups) composed of representatives of institutions, universities and ministries. Board composed of President and Vice-President of Council and chairman of working groups supervise work. Administration in hands of managing director.	Grants: (a) to research workers for research in universities and elsewhere on their own subject (about 50); (b) to institutions for special projects and for creating new research institutes; (c) for publications.
Pakistan	Council of Scientific and Industrial Research	1953	Semi-govern-mental, admini-strative, autonomous body	Ministry of Industries (through Department of Scientific and Industrial Research)	Yes	Council consists of 9 government representatives; 5 representatives of universities, donors and representatives for the provinces, etc. plus 10 other members of whom 6 are scientists appointed by the government. Governing Body of 16 comprising representatives 5 government ministries, universities and individuals.	Research fellowships.
Philippines	National Research Council of the Philippines	1933	Govern-mental, advisory	University of the Philippines	No	Council membership 150, comprising original charter members appointed by President of the country and members elected by the Council. Policy and super-	Grants-in-aid for equipment and technical assistance in connexion with special projects.

						vision determined by Executive Board and Board of Regents of the University.	
Spain	Consejo Superior de Investigaciones Científicas	1939	Semi-governmental, administrative	Ministry of Education (admin.)	Yes	Plenary Council consists of 30 regular representatives of each of the institutions, honorary members and corresponding members. Executive Board, elected by the Council, composed of chairman, 3 vice-chairmen, secretary, comptroller and 2 representatives of each institute.	Fellowships for post-graduate work at home and abroad.
Sweden	Statens naturvetenskapliga Forskningsrad	1946	Governmental, advisory, administrative (finance)	Minister of Education	No	Council composed of President appointed by government and 8 other members, 4 elected by universities and Academy of Sciences, 2 scientists appointed by government, 2 proposed by Council.	Fellowships for study abroad. Research contracts (in 1950-51, 142 grants including fellowships were awarded). Grants: (a) to institutions; (b) for publications.
	Statens tekniska Forskningsrad	1942	Governmental, advisory, administrative (finance)	Ministry of Commerce	No	Council composed of 8 persons appointed by the King on recommendations of institutes of technology, universities, Academy of Engineering Science and relevant associations.	Scholarships. Research contracts.

Country	*Research council*	*Date of foundation*	*Nature*	*Responsible or affiliated to*	*Research laboratories under direct control*	*Composition of council and governing bodies*	*Chief types of subvention for research and number per year*
Switzerland	Fonds National Suisse de la Recherche Scientifique	1952	Private foundation	Federal Department for Home Affairs	No	Council of the Foundation composed of representatives of educational, scientific, federal and cantonal organizations. The National Research Council (executive organ) is composed of 11 members, 7-9 of which are scientists.	Scholarships for training. Fellowships for research at home and abroad. Grants for technical workers for technical assistance and equipment. Grants to institutions for maintenance. Grants for publications.
Union of South Africa	South African Council for Scientific and Industrial Research	1945	Semi-governmental	Minister of Economic Affairs	Yes	Council composed of 12 members appointed by Governor-General.	Senior bursaries for independent workers and student bursaries for research workers under training. (In 1951-52, 62 bursaries were awarded and 24 grants for the employment of research assistants.)
United Kingdom	Department of Scientific and Industrial Research	1916	Governmental, advisory, administrative	Lord President of the Council	Yes	Department controlled by Committee of Privy Council for Scientific and Industrial Research, though in practice, Lord President acts for the committee after receiving advice of Advisory Council. Composition of latter not defined but includes some 12 scientists and industrialists appointed by Lord President after consultation with President of Royal Society.	Maintenance grants to students for equipment. (In 1950-51: 382 new awards made.) Research grants to established research workers for special investigations. (In 1950-51, 50 awards.) Senior research awards intended for scientists of proven research ability. (In 1951-52: 3 new awards).
U.S.A.	National	1916	Autonomous	President	No	Membership of Research	NAS-NRC administers a

U.S.A.	National Academy of Sciences-National Research Council (NAS-NRC)	1916	Autonomous body, non-governmental, advisory	President of the Senate	No	Membership of Research Council composed of representatives of approximately 100 scientific and technical societies, representatives of government, scientific bureaux and individual scientists. Policy determined by Governing Board composed of members of the Council of the National Academy of Sciences and of the Executive Board of the National Research Council.	NAS-NRC administers a large number of fellowships supported by organizations such as the Rockefeller Foundation, the American Cancer Society, Merck and Co., the Radio Corporation of America, the National Foundation for Infantile Paralysis, the Atomic Energy Commission, and the National Science Foundation—all for United States nationals.
	National Science Foundation	1950	Governmental, advisory, administrative (finance)	President of the United States of America	No	National Science Board consists of 24 members appointed by President with advice of Senate plus Director *ex officio*. There is an Executive Committee composed of 9 members of the Board elected by the Board and the Director *ex officio*.	Graduate fellowships. (In 1952-53: 624 fellowships awarded.) Grants to institutions for basic research by individual investigation (since October 1952: 177 awards). Scientific conferences and travel grants (35 awards). Miscellaneous (15 awards).
Yugoslavia	Akademiski Savet FNRJ	1948	Advisoy, administrative (finance)	Government	Yes	Council composed of 3 representatives of the 3 Academies. Members elected for 3 years. Executive elected by Council from among themselves.	Scholarships for study abroad.

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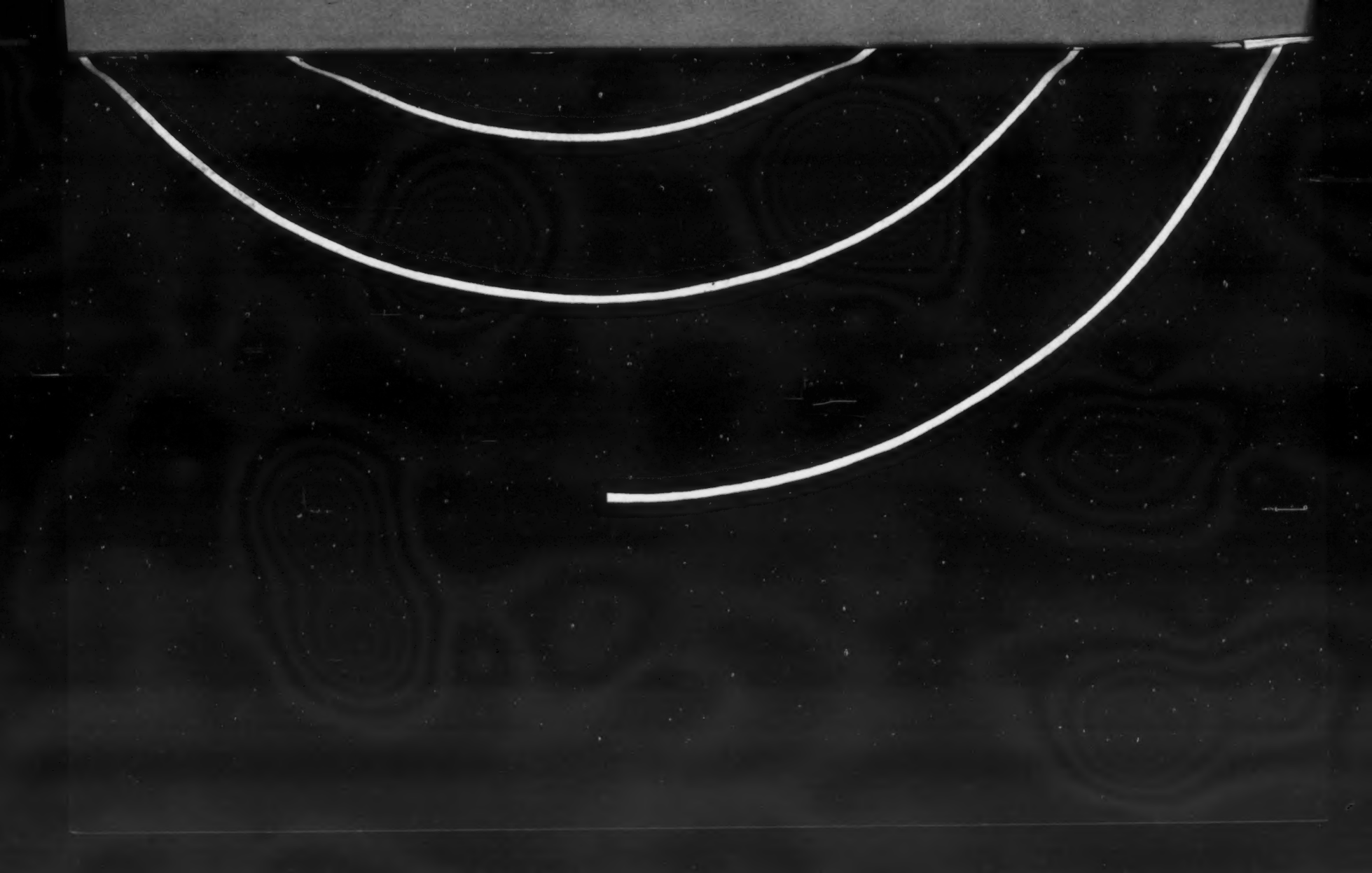
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